

LUNGKOMPLIKATIONER EFTER ELEKTIV GALLSTENS- ELLER MAGSÅRSKIRURGI

Incidens, riskfaktorer, möjligheter till
prediktion samt klinisk betydelse

Jan Eric Wirén



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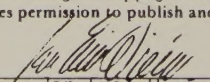
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Title and subtitle PULMONARY COMPLICATIONS FOLLOWING ELECTIVE SURGERY FOR GALLBLADDER DISEASE OR PEPTIC ULCER. Incidence, risk factors, prediction and clinical significance.		
Abstract The study deals with pulmonary complications in connection with elective upper abdominal surgery for gallbladder disease or peptic ulcer. The results are based on 53 men, aged 41-72 years. Four of them (8 %) developed clinical signs of pulmonary complications after surgery, 28 (54 %) had chest X-ray abnormalities postoperatively and 23 (43 %) had arterial hypoxemia. At least one of the criteria of pulmonary complication was fulfilled by 79 % of patients. Old age, overweight, smoking and chronic bronchitis were found to be risk factors for pulmonary complications. The possibility of identifying individuals with increased risk was improved by addition of spirometry to the preoperative assessment. FRC-CC < -0.1 l in supine position, indicating "airway closure" during tidal breathing, implied an increased risk of postoperative chest X-ray abnormalities, while a WOV > 35 l in the sitting position, indicating uneven pulmonary gas mixing, implied an increased risk of developing arterial hypoxemia. Only two out of the 39 patients with chest X-ray abnormalities and/or arterial hypoxemia were in need of specific treatment. In the other cases there was no difference as regards the postoperative course or the length of hospital stay between those with and without pulmonary complications. At the post-operative spirometry, 3-5 days after surgery, however, there was a greater reduction of lung volumes in those with chest X-ray abnormalities and/or arterial hypoxemia than in those without these complications. At the follow-up 1-2 years after discharge from hospital all but one had normal arterial blood gas tensions and all had normal chest X-rays. The values from spirometry had returned to preoperative levels and so had the results of the exercise test in the groups of patients with chest X-ray abnormalities and/or arterial hypoxemia as well as among patients without these complications.		
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Denna undersökning har möjliggjorts genom ekonomiskt stöd från Nationalföreningen mot Hjärt- och Lungsjukdomar samt från Medicinska Fakulteteten, Lunds Universitet.

Till alla medarbetare och vänner, som har bidragit till detta arbete, riktar jag mitt varma tack!

Jan Eric Wirén



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Denna avhandling bygger på följande delarbeten:

- I. Respiratory complications after upper abdominal surgery. The incidence of chest X-ray abnormalities, arterial hypoxemia and clinically recorded pulmonary complications.
Tillsammans med L. Janzon & C. Hellekant
Acta Chir Scand 147:623-627, 1981.
- II. Pre- and postoperative lung function in sitting and supine position related to postoperative chest X-ray abnormalities and arterial hypoxemia. A clinical study on 41-72 year-old men undergoing elective upper abdominal surgery.
Tillsammans med S.E. Lindell & C. Hellekant
Accepterat för publicering i Clin Physiol.
- III. Risk factors for postoperative respiratory complications and their predictive value. A study in 40-75 year-old men undergoing elective surgery for peptic ulcer or gallbladder disease.
Tillsammans med L. Janzon
Acta Chir Scand 148:479-484, 1982.
- IV. Respiratory complications following surgery. Improved prediction with preoperative spirometry.
Tillsammans med L. Janzon
Insänt till Acta Anaesth Scand.
- V. The clinical significance of postoperative chest X-ray abnormalities, arterial hypoxemia and clinically recorded respiratory complications.
Tillsammans med L. Janzon & C. Hellekant
Acta Chir Scand 148:553-556, 1982.

Referens till dessa arbeten göres med romerska siffror.

Risken för lungkomplikationer i anslutning till det kirurgiska ingreppet beror på en rad olika faktorer som t.ex. patientens ålder och vikt, valet av anestesimetod samt postoperativa vård- och övervakningsrutiner. Skillnader i det här avseendet förklarar till viss del varför incidensen i publicerade arbeten varierar mellan 0.1 och 70 % (Latimer et al. 1971). Risken för lungkomplikationer beror också på vilka metoder och vilka kriterier man använt vid definitionen av lungkomplikation. Studier baserade på kliniska tecken har genomgående redovisat lägre incidens än studier där man använt sig av postoperativ lungröntgen eller mätning av den arteriella syrgasspänningen (Rudnikoff & Headland 1951; Wiklander & Norlin 1957; Albért et al. 1964; Hamilton et al. 1964; Wightman 1968; Molnar et al. 1970; Szczepanski et al. 1973). För att kunna studera incidensen i olika studier samt hur risken påverkas av olika typer av ingrepp och anestesimetoder och andra potentiella riskfaktorer är det väsentligt att få ett tillförlitligt mått på hur frekvensen av lungkomplikationer påverkas av valet av metod. Även om det från tidigare undersökningar finns uppgifter om incidensen av lungröntgenförändringar, arteriell hypoxemi och kliniskt upptäckta komplikationer från lungorna, finns det ingen tidigare studie, där man i ett enhetligt material studerat frekvensen av dessa komplikationer och hur väl dessa tre metoder överensstämmer.

Olika försök har gjorts att identifiera de individer som löper störst risk att drabbas av lungkomplikationer. Den preoperativa andningsfunktionen har i en rad fall-kontrollstudier jämförts hos individer med och utan postoperativa lungkomplikationer (Stein et al. 1962; Palmer & Gardiner 1964; Appleberg et al. 1974; Fibuch et al. 1975; Hedenstierna & Wiklund 1980). Resultaten från dessa undersökningar varierar och detta förklaras sannolikt till en del av skillnader i metodval mellan olika undersökningar. Tidigare studier av lungfunktionen har vanligtvis genomförts med patienten i sittande ställning. Lungfunktionen varierar emellertid i sittande och liggande ställning. T.ex. avstängs de perifera luftvägarna tidigare under utandning i liggande än i sittande ställning (McCarthy et al. 1972). Detta bör ha klinisk betydelse, eftersom patienten under operationen och i den omedelbara postoperativa fasen befinner sig i liggande ställning. Preoperativ spirometri-undersökning borde kanske därför göras med patienten i liggande ställning. Ålder, vikt, rökning, kronisk bronkit

och ingreppets längd har i en del studier uppvisat ett samband med risken för postoperativa lungkomplikationer (Morton 1944; Dripps & Deming 1946; Thorén 1954; Wiklander & Norlin 1957; Nunn 1965; Wightman 1968; Latimer et al. 1971; Szczepanski et al. 1973; Hansen et al. 1977). Fynden är emellertid inte samstämmiga och detta förklaras åter till stor del genom skillnader i patienturval och typ av ingrepp men också av skillnader i metoder och definition av lungkomplikationer.

Möjligheten till prediktion av postoperativa lungkomplikationer baserad på patientens ålder, vikt, rökvanor och symptom från andningsvägarna är otillräckligt belyst. Rimligen borde möjligheterna att identifiera de individer som löper störst risk att drabbas av lungkomplikationer kunna förbättras genom att addera preoperativ spirometri till den preoperativa riskvärderingen baserad på patientens ålder, rökvanor, kroppsvikt och eventuella symptom på obstruktiv lungsjukdom. Detta har inte gjorts tidigare. Även om det finns en rad undersökningar av incidensen av postoperativa lungkomplikationer, finns det få arbeten som berör andningsfunktionen hos dem som drabbats av lungkomplikationer (Brattström 1954; Palmer & Gardiner 1964; Collins et al. 1968; Latimer et al. 1971) och hur det omedelbara postoperativa förloppet påverkas av dessa komplikationer. I den undersökning som gjordes av Rudnikoff & Headland (1951) behövde bara var tredje patient med lungröntgenförändringar aktiv behandling. Wiklander & Norlin (1957) fann i sin fall-kontrollstudie ingen skillnad i vårdtid hos patienter med och utan lungkomplikationer. Konsekvenserna på kort och lång sikt har emellertid inte tidigare studerats med hänsyn till olika metoder.

Målsättning

- (1) Att studera incidensen av postoperativa lungröntgenförändringar, arteriell hypoxemi samt kliniskt symptomgivande lungkomplikationer hos 40-75-åriga män, som opererats elektivt för gallsten eller magsår.
- (2) Att studera den pre- och postoperativa lungfunktionen hos patienter med lungröntgenförändringar respektive arteriell hypoxemi.
- (3) Att studera incidensen av postoperativa lungkomplikationer i relation till ålder, vikt, rökning, kronisk bronkit samt ingreppets längd.
- (4) Att studera möjligheten till preoperativ identifiering av högriskpatienter på basen av ålder, vikt, rökvanor, luftvägssymptom samt preoperativ lungfunktion mätt med spirometri.
- (5) Att jämföra det postoperativa förloppet och rehabiliteringen hos patienter med och utan lungröntgenförändringar, arteriell hypoxemi respektive kliniska tecken på komplikationer från andningsvägarna.

Patienter

Undersökningen genomfördes under tidsperioden maj 1975 - juni 1976. Samtliga män i åldrarna 40-75 år som intogs från väntelistan till vissa vårdavdelningar för operation på grund av magsår eller gallsten var kvalificerade att delta i undersökningen. Totalt ingår 53 män i studien. Av dessa opererades 29 för gallsten och 24 för magsår. Medianåldern i gruppen var 53 år med en spridning från 41 till 72 år. Tjugoen av patienterna var icke-rökare, 32 rökare. Tio uppfyllde frågeformulärets kriterier för kronisk bronkit. Samtliga dessa var rökare. Ytterligare 34 patienter kvalificerade för deltagande i undersökningen med hänsyn till ålder och ingreppets natur men kom av skilda skäl inte med. I en del fall förklaras detta av att de intogs tidigare än planerat och det preoperativa utredningsprogrammet kunde då inte genomföras i enlighet med studiens intentioner. En del vägrade att delta i undersökningen, ytterligare en grupp uteslöts närmast på grund av språksvårigheter. Vad gäller ålder, rökvanor och vårdtid samt incidensen av kliniskt registrerade lungkomplikationer skiljer sig bortfallsgruppen inte från gruppen som redovisas i den aktuella undersökningen.

Fyrtionio av de 53 patienterna inbjöds 1-2 år efter utskrivningen till en uppföljning med ny lungfunktionsundersökning och arbetsprov. I samband med detta gjordes också en intervju med avseende på symptom från andningsvägarna och sjukdomsförlopp efter utskrivningen från sjukhuset. Åtta patienter kom inte till uppföljningsundersökningen, men fyra av dessa kunde nås för en intervju.

Metoder

Vårdrutiner: Alla patienter fick andningsinstruktion och sjukgymnastik före operationen och alla patienter erhöll andningsgymnastik ett par timmar efter operationen. Samtliga mobiliserades dagen efter det operativa ingreppet.

Kirurgi: Cholecystectomi utfördes som enda ingrepp i 27 av de 29 fallen som opererades för gallsten. I två fall genomfördes cholecystectomi plus choledochotomi. Samtliga opererades med hjälp av arcussnitt. Magsårsoperationen genomfördes som vagotomi i sju fall, vagotomi plus pyloroplastik i 11, resek-

tion ad modum Billroth I i tre samt resektion ad modum Billroth II i tre fall. Nio patienter opererades med hjälp av transversellt snitt, 15 med medellinjesnitt.

Narkosmetod: I samtliga fall inleddes narkosen med thiopentalnatrium intravenöst. Efter muskelrelaxation intuberades patienterna endotrachealt och ventilerades manuellt med oxygen-lustgas. I 29 fall kompletterades lustgasen endast med intravenösa analgetika. Tjugotre patienter fick både halothan och intravenösa analgetika. En patient opererades i eteranestesi.

Samtliga de som opererades för gallsten och tre av dem som opererades för magsår erhöll preoperativt intercostalblockad med bupivacain (Marcain®) 0.5 %.

Rökvanor och luftvägssymptom: Den preoperativa intervjun med avseende på rökvanor och symptom från andningsvägarna genomfördes med hjälp av ett strukturerat frågeformulär (Rose & Blackburn 1968). Det kliniska förloppet efter utskrivningen framför allt med hänsyn till symptom i form av hosta, upphostning, andningssmärta och dyspné under de första 2-3 veckorna efter utskrivningen kartlades på samma sätt med strukturerat frågeformulär.

Kroppsmassa: Kroppsmassan uttrycktes som body mass index, BMI, vilket är vikten i kg/längden² i m (Keyes et al. 1972).

Arbetsprov: Cykelergometri utfördes preoperativt och 1-2 år postoperativt. Undersökningen utfördes med ökning av belastningen med 10 W/min (Larsson et al. 1976).

Spirometri: Spirometriundersökning genomfördes vid tre tillfällen: (1) preoperativt inom tre veckor före operationen; (2) postoperativt 3-5 dagar efter operationen; (3) vid efterundersökningen 1-2 år efter operationen. Mätningarna gjordes i sittande och liggande ställning vid tillfälle 1 och 2 (MVV dock endast i sittande ställning). Vid tillfälle 3 gjordes mätningarna endast i sittande ställning och omfattade då ej CC och SI.

Vitalkapacitet (VC), forcerad expiratorisk volym 1:a s (FEV_{1.0}) och maximal volontär ventilation per minut (MVV) mättes med s.k. Bernstein-spirometer (Berglund et al. 1963; Birath et al. 1963). Funktionell residualkapacitet (FRC), residualvolym (RV) och total lungkapacitet (TLC) mättes med kväveut-

sköljningsteknik (Bouhuys et al. 1956). Denna teknik användes också för att beräkna wash-out volume (WOV), d.v.s. den volym inandad oxygen som erfordras för att reducera kvävekoncentrationen i utandningsluften till 2 % (Arborelius et al. 1974) och lung clearance index (LCI) = WOV/FRC (Bouhuys et al. 1956). "Single breath" kväveutsköljningsteknik användes för att mäta closing capacity (CC), d.v.s. den mängd luft som finns kvar i lungorna då avstängning av perifera luftvägar börjar ske under utandning och slope index (SI), d.v.s. förändringen i kvävekoncentrationen under alveolära platån (Oxhøj & Bake 1974). Den preoperativa mätningen av CC kunde ej genomföras hos fyra patienter. På grund av smärta var det ej möjligt att mäta CC postoperativt. Eftersom referensvärden ej finns tillgängliga för spirometridata i liggande ställning, användes absolutvärden i analyserna.

Lungröntgen: Lungröntgen utfördes 3-5 dagar samt 1-2 år efter operationen. Undersökningen omfattade frontalbild och sidobild i sittande ställning. Alla bilderna granskades av samme röntgenolog, som ej hade tillgång till kliniska uppgifter om patienterna.

Arteriell syrgasspänning: Mätning av den arteriella syrgasspänningen gjordes med Clark-elektrod enligt Sundström (1975). Mätningarna utfördes i anslutning till pre- och postoperativ spirometri, dessutom på andra postoperativa dagen. Det lägsta postoperativa värdet användes för att avgöra om patienterna drabbats av postoperativ hypoxemi. Ytterligare en mätning av den arteriella syrgasspänningen gjordes vid uppföljningsundersökningen 1-2 år efter operationen.

Statistiska metoder: Student's t-test användes för jämförelse mellan grupperas medelvärden och parat t-test användes för jämförelser inom grupper (Pedersen & Hofsten 1973).

Lungkomplikationernas samband med ålder, vikt, rökning, kronisk bronkit och ingreppets längd studerades med hjälp av odds ratio (Fleiss 1973).

		Lungkomplikation	
		Ja	Nej
Positiv faktor eller test	Ja	a	b
	Nej	c	d

$$OR = \frac{a \cdot d}{b \cdot c}$$

Odds ratio ger ett mått på oddsen att hitta den förmodade riskfaktorn hos en individ med komplikation i jämförelse med motsvarande odds hos individer utan komplikationer. Ett odds ratio > 1.0 talar för ett samband mellan den förmodade riskfaktorn och förekomsten av komplikation och ger ett kvantitativt mått på graden av samband. För att studera hur ålder, kroppsvikt och ingreppets längd påverkade risken för lungröntgenförändringar respektive arteriell hypoxemi indelades materialet i kvartiler med avseende på dessa riskfaktorer. Den lägsta kvartilen användes som referensgrupp. Bearbetningen med avseende på kliniskt registrerade komplikationer är baserad på en medianindelning. Vid utvärdering av rökning och kronisk bronkit användes icke-rökare respektive patienter utan kronisk bronkit som referensgrupp.

Det prediktiva värdet för riskkvartilerna II, III och IV beräknades i enlighet med den metod, som beskrivits av Galen & Gambino (1975). I fyrfältstabellen ovan motsvarar

$\frac{a}{a + b} \times 100 \%$ det prediktiva värdet av ett positivt test. Detta är ett mått på sannolikheten att en individ med den förmodade riskfaktorn skall drabbas av lungkomplikation.

$\frac{b}{a + b} \times 100 \%$ utgör andelen falskt positiva. Det prediktiva värdet av ett negativt test beräknades i tabellen ovan som

$\frac{d}{c + d} \times 100 \%$. Detta värde anger ett mått på sannolikheten att en individ utan den förmodade riskfaktorn inte drabbas av lungkomplikation.

$\frac{c}{c + d} \times 100 \%$ anger andelen falskt negativa. Testets sensitivitet beräknades som

$\frac{a}{a + c} \times 100 \%$, specificiteten $\frac{d}{b + d} \times 100 \%$.

Definitioner

Rökare: Den som regelbundet rökt minst 1 g tobak per dag under det senaste året.

Icke-rökare: Den som ej rökt månaden före operationen.

Kronisk bronkit: Produktiv hosta under minst tre månader i mer än två på varandra följande år (A report to the Medical Research Council by their Committee on the Aetiology of Chronic Bronchitis 1965).

Postoperativa lungkomplikationer definierades såsom:

(a) Lungröntgenförändringar: Stora: segmentella atelektaser eller mer än 4 cm stora lamellära atelektaser med eller utan infiltrat. Små: Mindre än 4 cm stora lamellära atelektaser eller små infiltrat.

(b) Arteriell hypoxemi: Reduktion av den arteriella syrgasspänningen med mer än 1.5 kPa jämfört med preoperativt värde. (Jämförelse mellan två mätningar hos samma individ under normala förhållanden visade en reduktion > 1.5 kPa i endast 2 %).

(c) Kliniskt konstaterade komplikationer: Endast fall där det klart i journalen framgår att patienten drabbats av en lungkomplikation räknades som kliniskt konstaterade komplikationer.

Incidensen av postoperativa lungkomplikationer (I)

Resultat

Postoperativ lungröntgen utfördes ej på en patient. Hos övriga 52 fanns postoperativa lungröntgenförändringar i 28 fall (54 %), varav 16 klassificerades som stora.

Postoperativ arteriell hypoxemi förekom hos 23 av de 53 patienterna (43 %).

Kliniskt konstaterade komplikationer fanns hos fyra patienter (8 %). En 43-årig rökare utvecklade dyspné postoperativt. Lungröntgen visade en stor atelektas. En 71-årig rökare fick exacerbation av kronisk bronkit. En 44-årig icke-rökare visade tecken på övre luftvägsinfektion och hade hosta en månad efter operation. En 43-årig rökare fick lungemboli. Fyrtioen patienter (79 %) drabbades av åtminstone en av de lungkomplikationer som definierats ovan. Hos 12 patienter (23 %) fanns både lungröntgenförändringar och arteriell hypoxemi. Två av dessa hade även kliniskt konstaterade lungkomplikationer. Enbart arteriell hypoxemi eller lungröntgenförändringar fanns hos 11 (21 %) respektive 16 (31 %) patienter.

Kommentarer

Incidensen av lungkomplikationer i anslutning till kirurgi är i hög utsträckning en funktion av den metod man väljer. Den stora skillnaden mellan resultat baserade på kliniska tecken och symptom noterade i patientens journal och resultat baserade på postoperativ lungröntgen respektive mätning av arteriell syrgasspänning är uppenbarligen av betydelse, då man jämför incidensen av lungkomplikationer efter olika former av kirurgi och då man bedömer riskfaktorer och kliniska konsekvenser av lungkomplikationer.

Pre- och postoperativ lungfunktion i sittande och liggande ställning i relation till postoperativa lungkomplikationer (II)

Resultat

Patienter som utvecklade stora postoperativa lungröntgenförändringar hade signifikant lägre preoperativa värden för TLC (sittande och liggande), FRC (sittande och liggande), FRC-CC (sittande och liggande), WOV (sittande och liggande) och RV (liggande) än patienter med normal postoperativ lungröntgen. Den postoperativa reduktionen av TLC, FRC och WOV, mätt i sittande, var signifikant större hos patienter med stora postoperativa lungröntgenförändringar än hos patienter utan. SI ökade mest hos patienter med stora lungröntgenförändringar. Alla patienter som utvecklade stora lungröntgenförändringar hade negativa preoperativa värden för FRC-CC i liggande som tecken på "luftvägs-avstängning" inom tidalvolymen.

Patienter med postoperativ arteriell hypoxemi hade signifikant högre preoperativa värden för WOV och LCI, både i sittande och liggande, än patienter utan postoperativ arteriell hypoxemi. Den postoperativa nedgången i TLC, FRC och WOV, alla i sittande, var signifikant större hos patienter med postoperativ hypoxemi än hos patienter utan. SI i liggande ställning ökade mera postoperativt hos hypoxiska än hos normala patienter. Postoperativt var MVV och FEV_{1.0} signifikant lägre hos hypoxiska än hos normala patienter.

Kommentarer

Preoperativt FRC-CC i liggande ställning uppvisade ett starkt samband med postoperativa lungröntgenförändringar och borde därför vara ett lämpligt test för prediktion av lungröntgenförändringar. Preoperativ WOV i sittande ställning hade det starkaste sambandet med postoperativ arteriell hypoxemi och borde därför vara det lämpligaste testet för preoperativ identifiering av högriskpatienter för postoperativ hypoxemi.

Konventionell spirometri i sittande ställning var ej underlägsen motsvarande undersökning i liggande ställning vid pre- och postoperativ bedömning med hänsyn till lungkomplikationer. Däremot visade de preoperativa FRC-CC-mätningarna i liggande ställning det starkaste sambandet med postoperativa lung-röntgenförändringar.

Resultat

Risken för postoperativa lungröntgenförändringar påverkades av ingreppets längd samt patientens vikt och ålder. Odds ratios i den översta kvartilen med hänsyn till dessa tre faktorer varierade från 1.4 till 2.6. Incidensen i den översta riskkvartilen skiljde sig emellertid inte signifikant från incidensen i hela materialet och det var därför inte möjligt att prediktera uppkomsten av lungröntgenförändringar på basen av patientens ålder och kroppsvikt. Postoperativa lungröntgenförändringar kunde ej heller förutsägas genom kännedom om rökvanor och förekomst av kronisk bronkit.

Risken för postoperativ arteriell hypoxemi påverkades av ingreppets längd samt patientens ålder och vikt. Odds ratio i den översta kvartilen med hänsyn till dessa tre faktorer varierade från 1.1 till 5.0. Rökning och kronisk bronkit ökade risken för postoperativ hypoxemi med 1.4 respektive 2.3 gånger. Incidensen i den högsta riskkvartilen, respektive hos rökare och patienter med kronisk bronkit, skiljde sig emellertid inte från incidensen i hela materialet och det är därför inte möjligt att prediktera uppkomsten av postoperativ arteriell hypoxemi på basen av patientens ålder, kroppsvikt, rökvanor och eventuella symptom från andningsvägarna.

Ålder, BMI och anestesitid ovan medianen var ej förenade med ökad risk för postoperativa, kliniskt konstaterade komplikationer. Däremot var rökning och kronisk bronkit förenade med 2.1 respektive 1.5 gångers riskökning. Incidensen hos rökare och patienter med kronisk bronkit skiljde sig emellertid inte signifikant från incidensen i hela materialet och det var därför inte möjligt att prediktera uppkomsten av postoperativa, kliniskt konstaterade komplikationer på basen av rökvanor och symptom från andningsvägarna.

Kommentarer

Hög ålder, övervikt, rökning, kronisk bronkit samt långa ingrepp var alla förenade med ökade risker för åtminstone någon typ av postoperativ lungkomplikation. Sambandet var emellertid inte tillräckligt starkt för att tillåta identifiering av högriskpatienter.

Kan man förbättra möjligheten att förutsäga postoperativa lungkomplikationer med hjälp av preoperativ spirometri? (IV)

I detta arbete har patienter med ålder under medianen, BMI under medianen, icke-rökare och patienter utan kronisk bronkit, vilka dessutom preoperativt hade $FRC-CC > -0.1$ l respektive $WVO < 35$ l, utgjort referensgrupper.

Resultat

Lungröntgen: Patienter med ålder ovan medianen, BMI ovan medianen samt rökare och patienter med kronisk bronkit jämfördes med referensgrupperna. Odds ratios var då 0.7-8.3. Odds ratio för dem som dessutom hade ett preoperativt $FRC-CC$ lägre än -0.1 l var 5.0-13.0. Det prediktiva värdet baserat på denna kombinerade riskbedömning varierade mellan 67 och 75 %.

Hypoxemi: Patienter med ålder ovan medianen, vikt ovan medianen, rökare och patienter med kronisk bronkit jämfördes med referensgrupperna. Odds ratios var 2.0-4.2. Odds ratios för dem som dessutom hade ett preoperativt $WVO > 35$ l var 3.8-9.0. Det prediktiva värdet baserat på denna kombinerade riskbedömning varierade mellan 54 och 67 %.

Kommentarer

Möjligheten att förutsäga uppkomsten av postoperativa komplikationer hos gamla och överviktiga patienter, patienter som röker eller har symptom från andningsvägarna kunde förbättras med hjälp av preoperativ spirometri. $FRC-CC$ lägre än -0.1 l ökade möjligheten till prediktion av lungröntgenförändringar, $WVO > 35$ l möjligheten till preoperativ identifiering av patienter med störst risk för arteriell hypoxemi.

Den kliniska betydelsen av postoperativa lungkomplikationer (V)

Resultat

Vårdtiden för patienter med lungkomplikationer skiljde sig inte signifikant från vårdtiden hos patienter utan.

Som ett mått på det kliniska efterförloppet mättes kroppstemperaturen på morgonen på tredje dagen. Patienter med lungkomplikationer skiljde sig i detta avseende ej från patienter utan komplikationer.

Tio patienter uppgav symptom från andningsvägarna de 2-3 första veckorna efter utskrivningen. Antalet patienter med luftvägssymptom var ej större bland patienter med postoperativa lungröntgenförändringar än hos patienter med normal lungröntgen. Däremot var luftvägssymptom hos patienter med postoperativ hypoxemi och/eller kliniskt konstaterade komplikationer 3-5 gånger vanligare än hos patienter utan dessa komplikationer.

Medelvärdena från preoperativt arbetsprov, spiometri och arteriell syrgas-spänning jämfördes med motsvarande medelvärden vid efterundersökningen. Härvid framkom inga statistiskt signifikanta skillnader varken hos patienter med eller hos patienter utan postoperativa lungkomplikationer.

Alla postoperativa lungröntgenförändringar hade försvunnit vid efterundersökningen.

Endast två av patienterna med lungröntgenförändringar och/eller hypoxemi fick behandling riktad mot lungkomplikationen.

Kommentarer

Det postoperativa förloppet påverkades i denna studie inte av vare sig lungröntgenförändringar eller arteriell hypoxemi. Rimligen representerar dock lungröntgenförändringar och arteriell hypoxemi tidiga tecken på potentiellt allvarliga lungkomplikationer. Modern postoperativ vård med andningsgymnastik och

tidig mobilisering är sannolikt förklaringen till dessa komplikationers benigna förlopp. Lungröntgenförändringar hos patienter utan kliniska symptom var i samtliga fall reversibla utan specifik behandling. Det kan därför inte anses motiverat att följa upp alla patienter med postoperativa lungröntgenförändringar med rutinmässig röntgenkontroll efter utskrivningen.

DISKUSSION

Det kirurgiska ingreppet kan i efterförloppet kompliceras av bl.a. sårinfektion och komplikationer från cirkulations- och andningsorgan. En postoperativ komplikation kan leda till en förlängning av vårdtiden och en förlängning av rehabiliteringen och innebär i allvarligaste fall en risk för patientens liv. Våra möjligheter att mildra konsekvenserna av en postoperativ komplikation förutsätter tidig diagnos och helst att man preoperativt kan identifiera de patienter som löper störst risk att drabbas. Den nu aktuella undersökningen bekräftar tidigare studier som visat att många patienter utvecklar lungkomplikationer i efterförloppet till det kirurgiska ingreppet. Inte mindre än åtta av tio patienter som togs in elektivt för operation på grund av gallsten eller magsår utvecklade någon form av lungkomplikation. Risken för lungkomplikation är uppenbarligen i hög grad en funktion av den metod man använder. En skattning av risken baserad på postoperativa lungröntgenundersökningar ger cirka sju gånger högre risk än om den är baserad på klinisk observation. Jämförbara incidenssiffror innebär inte nödvändigtvis att överensstämmelsen mellan de olika metoderna är god. Trettionio av patienterna utvecklade antingen lungröntgenförändringar eller arteriell hypoxemi i det postoperativa förloppet. Mindre än hälften av dem med lungröntgenförändringar hade arteriell hypoxemi och av dem med arteriell hypoxemi hade bara varannan patient påvisbara lungröntgenförändringar. Denna bristande överensstämmelse har diskuterats tidigare av bl.a. Hamilton et al. (1964), som hävdar att hypoxemin representerar mikroatelektaser som inte är möjliga att iakttaga på röntgenbilden. Dessa mikroatelektaser utvecklas enligt Hamilton et al. stegvis och det är först så småningom atelektasen blir möjlig att iakttaga på röntgenbilden. Lahnborg et al. (1976) hävdar i stället att hypoxemin är resultatet av en mikroembolisering till lungorna. Ytterligare en förklaring är att reducerade lungvolymer ger luftvägsavstängning och veno-arteriell shuntning (Alexander et al. 1973). Dessa hypoteser kan emellertid inte förklara avsaknaden av hypoxemi hos hälften av patienterna med stora atelektaser. En möjlig förklaring är naturligtvis att atelektasen har kommit först och att patienten håller på att utveckla hypoxemi. I undersökningen gjordes inga mätningar av den arteriella syrgasspänningen efter att röntgenfyndet konstaterades och det går därför inte att visa att så är fallet. Den mest sannolika förklaringen är emellertid att såväl perfusion som ventilation till det drabbade området är avstängda (Molnar et al. 1970).

Våra möjligheter att förhindra eller mildra konsekvenserna av postoperativa lungkomplikationer beror till stor del på vår förmåga att identifiera högriskpatienter. Undersökningen visar att lungkomplikationer i anslutning till det kirurgiska ingreppet inte är ett slumpmässigt fenomen och bekräftar i detta avseende en del tidigare studier (Morton 1944; Thorén 1954; Wiklander & Norlin 1957; Nunn 1965; Wightman 1968; Latimer et al. 1971; Szczepanski et al. 1973; Hansen et al. 1977). Gamla och överviktiga patienter, patienter som röker och som har obstruktiva symptom från andningsvägarna löper större risk att drabbas av lungkomplikationer. Den statistik som presenteras är självfallet behäftad med en viss osäkerhet genom det relativt ringa antalet patienter som ingår i undersökningen. Man kan också misstänka att en viss selektion kan ha förevarit genom att patienter med dåligt allmäntillstånd, allvarlig övervikt liksom patienter med uttalat obstruktiva lungsymptom inte har erbjudits elektiv operation. I jämförelse med den redovisade bortfallsgruppen föreligger emellertid ingen selektion. Sambandet med olika riskfaktorer illustreras av odds ratio som när det gäller studier av samband har två viktiga fördelar - den ger ett kvantitativt mått på graden av samband och är oberoende av materialets storlek. Presenterade samband representerar en punktskattning och det är därför självfallet svårt att invändningsfritt jämföra hypoxemi med lungröntgenförändringar. Det förefaller ändå som om olika riskfaktorer är en funktion av den metod man använder sig av. Exempelvis dubblade anestesitider överstigande tre timmar risken för lungröntgenförändringar men femdubblade risken för arteriell hypoxemi.

Även om olika riskfaktorer kan identifieras, är sambanden inte starka nog för att man preoperativt skall kunna identifiera de patienter som löper störst risk att drabbas av lungkomplikationer. Den preoperativa riskvärderingen måste därför kompletteras med andra hjälpmedel. Preoperativ spirometri förefaller i det här avseendet vara en möjlig utväg. De patienter som hade lungröntgenförändringar uppvisade vid den preoperativa spirometrin samtliga negativa värden för FRC-CC. De som drabbades av arteriell hypoxemi hade preoperativt signifikant högre medelvärde för WOV än patienterna utan hypoxemi. Möjligheten att förutsäga postoperativa lungkomplikationer hos högriskpatienter baserad på deras ålder, kroppsvikt, rökvanor samt förekomst av obstruktiva symptom från andningsvägarna tycks kunna förbättras genom att addera spirometri till den preoperativa utredningen. Resultaten talar för att tidig avstängning av luftvägarna lättare avslöjas om undersökningen genomförs med patienten i liggande ställning. Detta gäller inte övriga spirometri-variabler. Det prediktiva värdet

av preoperativ spirometri beror på var gränsen sätts för onormal FRC-CC respektive WOV. För att definiera dessa gränsvärden måste man beakta konsekvenserna av ett falskt positivt respektive falskt negativt testresultat. Modern postoperativ övervakning, tidig mobilisering och postoperativ andningsgymnastik är sannolikt effektiva hjälpmedel när det gäller att förhindra en allvarlig utveckling av en postoperativ atelektas respektive postoperativ arteriell hypoxemi. Konsekvensen av ett falskt positivt testresultat kan bli en skärpt postoperativ övervakning och kan praktiskt innebära ökade arbetsinsatser för vård- och laboratoriepersonal. Ett falskt negativt testresultat å andra sidan kan leda till otillräcklig postoperativ övervakning och därmed en ökad risk för utveckling av en allvarlig lungkomplikation. Gränserna för vad som utgör en abnorm spirometri bör därför vara vida i den preoperativa bedömningen. Patienter med postoperativ arteriell hypoxemi hade preoperativt tecken på sänkt ventilationseffektivitet, medan patienter med postoperativa lungröntgenförändringar i stället uppvisade låga statiska lungvolymmer. Denna bristande överensstämmelse kan tala för att hypoxemin respektive lungröntgenförändringarna avspeglar olika komplikationer med skild genes.

Fastän 75 % av patienterna utvecklade lungröntgenförändringar eller hypoxemi i det postoperativa förloppet, tycks dessa komplikationer ha liten klinisk relevans. Bara två av de 39 patienterna med lungröntgenförändringar eller arteriell hypoxemi behövde specifik behandling. I övriga fall var det ingen skillnad med avseende på det postoperativa förloppet eller vårdtiden hos dem med och utan lungkomplikationer. Patienternas rehabilitering och eventuella komplikationer efter utskrivningen baseras på en intervju, som gjordes relativt lång tid efter utskrivningstillfället. Självfallet måste därför denna information tolkas med viss försiktighet. Patienter som uppgav symptom från andningsvägarna efter utskrivningen behövde emellertid i inget fall specifik behandling. Vid den uppföljning som gjordes 1-2 år efter utskrivningen hade alla patienter normal lungröntgen och alla utom en normal arteriell syrgas-spänning. Uppenbarligen går därför dessa förändringar spontant i regress utan speciell behandling. Självfallet kan man ifrågasätta om hypoxemi respektive lungröntgenförändringar därför utgör valida parametrar på komplikationer från andningsvägarna, då ingen av patienterna behövde specifik behandling och komplikationerna spontant var reversibla. Emellertid kunde man hos patienter med lungröntgenförändringar och/eller arteriell hypoxemi vid den postoperativa spirometrin 3-5 dagar efter det kirurgiska ingreppet konstatera större lung-funktionspåverkan än hos patienter utan dessa komplikationer. Patienter med

postoperativ arteriell hypoxemi respektive postoperativa atelektaser bör därför betraktas som potentiella högriskindivider för allvarliga lungkomplikationer. Sambandet med rökning, kroppsvikt och förekomsten av obstruktiva symptom från andningsvägarna talar för att dessa komplikationer kan förebyggas genom en preoperativ intervention mot dessa riskfaktorer.

SAMMANFATTNING

Studien avser lungkomplikationer i anslutning till elektiv operation för gallsten eller magsår. Resultaten baseras på 53 män i åldern 41-72 år. Fyra av dessa (8 %) utvecklade postoperativt kliniska tecken på lungkomplikationer, 28 (54 %) utvecklade lungröntgenförändringar, 23 (43 %) arteriell hypoxemi. Åtta av tio patienter uppfyllde åtminstone något av kriterierna för lungkomplikation. Trettionio av patienterna utvecklade lungröntgenförändringar och/eller arteriell hypoxemi. Mindre än hälften av dem med lungröntgenförändringar hade arteriell hypoxemi. Av dem med arteriell hypoxemi hade bara varannan lungröntgenförändringar.

Gamla och överviktiga patienter, rökare och patienter med kronisk bronkit löpte större risk än övriga att drabbas av lungkomplikationer. Sambandet med dessa riskfaktorer var emellertid för svagt för att man preoperativt skulle kunna identifiera de individer som löpte störst risk. Möjligheten att identifiera högriskindivider kunde förbättras genom att addera spirometri till den preoperativa riskvärderingen baserad på ålder, vikt, rökvanor och symptom från andningsvägarna. $FRC-CC < -0.1$ l i liggande i kombination med någon av nämnda riskfaktorer innebar en ökad risk för postoperativa lungröntgenförändringar, medan en $WOV > 35$ l i sittande i kombination med någon av riskfaktorerna innebar en ökad risk för postoperativ arteriell hypoxemi.

Bara två av de 39 patienterna med lungröntgenförändringar och/eller arteriell hypoxemi behövde specifik behandling. I övriga fall var det ingen skillnad med avseende på det postoperativa förloppet eller vårdtiden mellan dem med och utan lungkomplikationer. Emellertid kunde man vid den postoperativa spirometrin, 3-5 dagar efter det kirurgiska ingreppet, konstatera en större reduktion av lungvolymer hos dem med lungröntgenförändringar och/eller arteriell hypoxemi än hos dem utan dessa komplikationer. Vid den uppföljning som gjordes 1-2 år efter utskrivningen hade alla utom en normal arteriell syrgasspänning, alla hade normal lungröntgen.

KONKLUSIONER

(1) Incidensen av lungkomplikationer i anslutning till elektiv gallstens- eller magsårskirurgi är beroende på vilken metod man använder sig av för att påvisa lungkomplikationer. Incidensen av postoperativa lungröntgenförändringar (54 %) och arteriell hypoxemi (43 %) var betydligt högre än risken för kliniskt symptomgivande lungkomplikationer (8 %). Överensstämmelsen mellan olika metoder var låg.

(2) Patienter med postoperativa lungröntgenförändringar hade lägre preoperativa värden för TCL, FRC, FRC-CC och WOV än patienter med normal postoperativ lungröntgen. Patienter med postoperativ arteriell hypoxemi hade preoperativt högre värden för WOV och LCI än patienter utan hypoxemi. Patienter med postoperativa lungröntgenförändringar och/eller arteriell hypoxemi hade en större postoperativ reduktion av TLC, FRC och WOV i sittande ställning än patienter utan dessa lungkomplikationer.

(3) Gamla och överviktiga patienter, rökare och patienter med kronisk bronkit löpte ökad risk för lungkomplikationer.

(4) Möjligheten att identifiera högriskindivider för postoperativa lungkomplikationer på basen av patientens ålder, vikt, rökvanor samt symptom på kronisk bronkit kunde förbättras genom att addera spirometri till den preoperativa värderingen. FRC-CC ökade möjligheten att hitta högriskindivider för lungröntgenförändringar. WOV ökade möjligheten att identifiera rökriskindivider för arteriell hypoxemi.

(5) Det postoperativa förloppet och rehabiliteringen efter utskrivningen skiljde sig inte hos patienter med och utan postoperativa lungkomplikationer. Såväl lungröntgenförändringar som arteriell hypoxemi gick spontant i regress utan specifik behandling.

SUMMARY IN ENGLISH

The study deals with pulmonary complications in connection with elective upper abdominal surgery for gallbladder disease or peptic ulcer. The results are based on 53 men, aged 41-72 years. Four of them (8 %) developed clinical signs of pulmonary complications after surgery, 28 (54 %) had chest X-ray abnormalities postoperatively and 23 (43 %) had arterial hypoxemia. At least one of the criteria of pulmonary complication was fulfilled by 79 % of patients; 75% of the patients developed chest X-ray abnormalities and/or arterial hypoxemia; only 43 % of those with chest X-ray abnormalities had arterial hypoxemia; only 52 % of those with arterial hypoxemia developed chest X-ray abnormalities.

Old patients and patients who are over-weight, smokers and patients with chronic bronchitis run a greater risk of pulmonary complications in the post-operative course. However, in this study the relationship between these risk factors was too weak to allow a preoperative identification of those who run the greatest risk. The possibility of identifying individuals with increased risk was improved by addition of spirometry to the preoperative assessment. FRC-CC < -0.1 l in supine position, indicating "airway closure" during tidal breathing, implied an increased risk of postoperative chest X-ray abnormalities, while a WOV > 35 l in the sitting position, indicating uneven pulmonary gas mixing, implied an increased risk of developing arterial hypoxemia.

Only two out of the 39 patients with chest X-ray abnormalities and/or arterial hypoxemia were in need of specific treatment. In the other cases there was no difference as regards the postoperative course or the length of hospital stay between those with and without pulmonary complications. At the postoperative spirometry, 3-5 days after surgery, however, there was a greater reduction of lung volumes in those with chest X-ray abnormalities and/or arterial hypoxemia than in those without these complications.

At the follow-up 1-2 years after discharge from hospital all but one had normal arterial blood gas tensions and all had normal chest X-rays. The values from spirometry had returned to preoperative levels and so had the results of the exercise test in the groups of patients with chest X-ray abnormalities and/or arterial hypoxemia as well as among patients without these complications.

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RESPIRATORY COMPLICATIONS AFTER UPPER ABDOMINAL SURGERY

The Incidence of Chest X-ray Abnormalities, Arterial Hypoxemia and Clinically Recorded Pulmonary Complications

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Abstract. The incidence of postoperative chest X-ray abnormalities, arterial hypoxemia and clinically recorded pulmonary complications was studied in fifty-two 40-75-year-old men admitted for elective surgery for peptic ulcer or gallbladder disease. Twenty-eight (54%) patients had an abnormal chest X-ray and twenty-three (43%) arterial hypoxemia, whereas only four patients (8%) were identified with clinical signs and symptoms of respiratory complications. Forty-one patients (79%) were found with pulmonary complications by at least one of the three methods. Twelve patients had both an abnormal chest X-ray and arterial hypoxemia. Only two of these were identified with clinical signs indicating pulmonary complications. The great discrepancy between results based on clinical signs and symptoms noted in the patients' records and results based on postoperative chest X-ray and measurements of the arterial oxygen tension, respectively, should be of great importance when comparing the incidence of pulmonary complications after different forms of surgery and when assessing risk factors and clinical consequences of respiratory complications.

Disordered pulmonary function has for many years been recognized as a potential complication to surgery and anaesthesia (Hewlett & Brantwaite, 1975). The incidence varies, however, from one study to another (Latimer, Dickman, Clinton Day, Gunn & DuWayne Schmidt, 1971) dependent on age and preoperative condition of the patients, different surgical and anaesthesiological procedures, different methods of study and different definitions of what constitutes a respiratory complication.

Postoperative cough, fever and rales have by many authors been used as signs of respiratory complications. In retrospective studies (Hamilton, McDonald, Fischer & Bethards, 1964; Albért, Löfström & Pernow, 1964), based on complications registered in the patients' records, the incidence varied between 4 and 5%, whereas in prospective studies with postoperative auscultation of the lungs, the incidence has been much higher. Thus, King

(1933) found signs and symptoms of respiratory complications in 46.8% of patients undergoing surgery for peptic ulcer and 35.6% of patients operated on for gallbladder disease. In another prospective study of patients operated on for gallbladder disease or peptic ulcer, Wightman (1968) found symptoms of postoperative respiratory complications in 21%.

Others have used chest radiography to study the incidence of postoperative respiratory complications. In 40 patients operated on with cholecystectomy Rudnikoff & Headland (1951) found an abnormal chest X-ray after operation in 28 patients (70%). Lung abnormalities in this study included all pulmonary changes not previously recorded. In a study by Thorén (1954) of patients undergoing cholecystectomy, postoperative chest radiography revealed atelectasis and/or pneumonia in only 12% of patients submitted for pre- and postoperative physiotherapy as compared to 42% in those not submitted for such treatment. The effect of pre- and postoperative physiotherapy on the incidence of respiratory complications as defined by chest radiography was also studied by Wiklander & Norlin (1957) in patients undergoing upper abdominal surgery. In their study postoperative atelectasis and/or pneumonia was found in 59% of the patients submitted for pre- and postoperative physiotherapy as compared to 77% of the control group. Szczepanski, Skaarup & Staehr-Johansen (1973) reported postoperative pulmonary complications as defined by chest radiography in 77% of patients undergoing surgery for peptic ulcer and in 52% of patients undergoing surgery for gallbladder disease. In this study even the slightest abnormality on the chest radiograph was registered as a pulmonary complication.

Table 1. Number of postoperative respiratory complications as defined by clinical signs, chest radiography and determination of oxygen tension

(a) Large (≥ 4 cm) lamellar or segmental atelectasis with or without infiltrates. (b) Small (< 4 cm) lamellar atelectasis or small infiltrates

Method of definition	Surgery for					
	Gallbladder disease		Peptic ulcer		All	
	Pulmonary complications		Pulmonary complications		Pulmonary complications	
	Yes	No	Yes	No	Yes	No
Clinical signs	3	26	1	23	4	49
Chest radiography (a)	9		7		16	
(b)	6	13	6	11	12	24
Arterial oxygen tension	11	18	12	12	23	30

Gordh, Linderholm & Norlander (1958), Nunn & Payne (1962), Diamant & Palmer (1966) and Knudsen (1970) have studied postoperative arterial oxygen tension after different forms of surgery. All reported a postoperative reduction of the arterial oxygen tension. According to Diamant & Palmer the most pronounced postoperative arterial hypoxemia was found in patients undergoing upper abdominal surgery.

Obviously, when comparing different studies, the incidence of chest X-ray abnormalities and arterial hypoxemia much exceeds the incidence of clinically recorded pulmonary complications.

The aim of the present study was to compare the incidence and interrelation of postoperative respiratory complications as defined by chest radiography, arterial oxygen tension and clinical signs in 40–75-year-old men undergoing elective surgery for peptic ulcer or gallbladder disease.

MATERIAL AND METHODS

The study period lasted from May 1975 to June 1976. Forty to seventy-five-year-old men admitted for elective surgery for peptic ulcer or gallbladder disease were included in the study. The preoperative assessment included a routine clinical examination, spirometry and determination of arterial oxygen tension. The postoperative evaluation included chest radiography, spirometry and determination of arterial oxygen tension. After the patients were discharged, their records were checked for notes explicitly stating that the patients had suffered from a postoperative pulmonary complication.

During the study period 91 men underwent elective surgery for peptic ulcer or gallbladder disease. In 34 patients, however, a complete assessment could not be performed. Most of these patients were admitted to the hospi-

tal earlier than originally planned, so a complete preoperative assessment according to the study programme could not be performed. Four patients refused to take part in the postoperative investigation. The present study was thus restricted to 53 patients. In one of these patients postoperative chest radiography was not carried out and the correlation studies are therefore based on 52 patients. In order to assess the degree of selection bias, available preoperative and postoperative data were analysed separately in those who were not included in the study programme. In terms of age, smoking habits and length of hospitalization no significant differences were found between those included and those not included in the presentation. The percentage of clinically registered pulmonary complications did not differ between the two groups. All patients were instructed preoperatively by a physiotherapist and all received physiotherapy within a few hours after the operation.

Surgical procedure

Twenty-nine patients were operated on for gallbladder disease. Cholecystectomy was performed in 27 cases and cholecystectomy plus choledochotomy in 2 cases. An oblique incision was used in all these patients. Twenty-four patients were operated on for peptic ulcer. Vagotomy was carried out in 7 patients, vagotomy plus pyloroplasty in 11, resection *ad modum* Billroth I in 3 and *ad modum* Billroth II in 3 patients. Among the patients operated on for peptic ulcer a transverse incision was used in 9 and a midline incision in 15.

Anaesthesiological procedure

In all patients anaesthesia was induced with thiopentone and maintained with nitrous oxide–oxygen. Twenty-three of the patients received both halothane and intravenous analgetics. In 29 of the patients nitrous oxide was supplemented only by intravenous analgetics. One patient was operated on in ether anaesthesia. Intercostal nerve-block with bupivacain 0.5% was given preoperatively to all of the patients operated on for gallbladder disease and to three of the patients operated on for peptic ulcer.

1. Chest radiography

The examination was performed 2–5 days after the operation. All films were examined by the same radiologist. Interpretation was made without information of the patient's clinical status.

Definition of postoperative chest X-ray abnormalities. **Major:** Segmental atelectases or more than 4 cm large lamellar atelectases with or without infiltrates. **Minor:** Less than 4 cm lamellar atelectases or small infiltrates.

2. Arterial oxygen tension

Arterial oxygen tension was determined in accordance with the method described by Sundström (1975) on the second day after operation and again 3–5 days after the operation. The lowest recorded value was used for classification of postoperative arterial hypoxemia.

Definition of postoperative arterial hypoxemia. Postoperative arterial hypoxemia was defined as arterial oxygen reduction of more than 1.5 kPa in comparison with the preoperative value. The defined cut-off point corresponds to the mean difference +2 S.E. of the mean difference between two determinations in the same individual.

3. Clinical signs and symptoms

After the patients had been discharged, their records were checked for notes made by the clinicians in the ward to see if the patients had suffered from respiratory complications after surgery.

Definition of registered pulmonary complications. The only cases counted were those where it was expressly stated by the clinician in the ward that the patient had suffered from a respiratory complication.

RESULTS

Postoperative chest X-ray abnormalities

(Table I)

In one patient postoperative chest radiography was not performed. In the remaining 52 patients 28 were found to have an abnormal chest X-ray (54%; 95% confidence interval: 41–68%). Of these 28 patients 16 (57%) had major abnormalities as defined above.

Postoperative arterial hypoxemia (Table I)

A significant reduction of arterial oxygen tension, i.e. more than 1.5 kPa was found in 23 out of 53 patients (43%; 95% confidence interval: 30–56%).

Pulmonary complications registered by the clinician (Table I)

In all, four cases (8%) had clinical signs of pulmonary complications after operation. Two of these had been operated on with cholecystectomy, one with cholecystectomy plus choledochotomy and one with vagotomy.

Fig. 1A illustrates the relation between post-

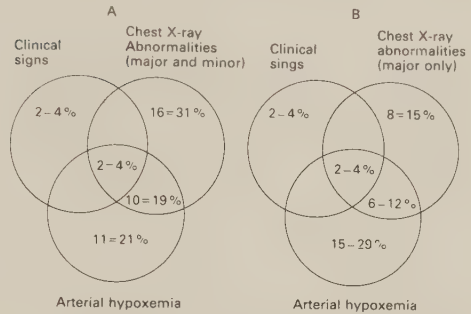


Fig. 1. Respiratory complications after upper abdominal surgery. Correlation between clinical signs, chest radiography and arterial oxygen tension ($n=52$). (A) Both major and minor chest X-ray abnormalities included; (B) only major chest X-ray abnormalities included.

operative clinical signs of respiratory complications, chest X-ray abnormalities and arterial hypoxemia. In 11 patients (21%) there were no postoperative complications as defined in this study. Forty-one patients (79%) had pulmonary complications by at least one of the three methods. In 12 patients (23%) there were chest X-ray abnormalities as well as arterial hypoxemia. Two of these were identified by the clinician as having pulmonary complications. Arterial hypoxemia and abnormal chest X-ray were the only signs of respiratory complications in 11 (21%) and 16 (31%) patients, respectively. Two patients (4%) had only clinical signs of respiratory complications.

Fig. 1B illustrates the corresponding comparison when restricting chest X-ray abnormalities to cases with large lamellar or segmental atelectases with or without infiltrates. Sixteen patients (31%) had large lamellar or segmental atelectases. Eight of these patients had postoperative arterial hypoxemia. Two of the eight patients with major chest X-ray abnormalities and arterial hypoxemia were identified clinically as having respiratory complications.

In patients without clinical signs and symptoms of respiratory complications and with normal chest X-ray the preoperative and postoperative aB- PO_2 difference varied from a maximum reduction of 3.7 kPa to a maximum increase of 1.6 kPa. In patients with major chest X-ray abnormalities preoperative–postoperative difference varied from a maximum reduction of 4.0 kPa to a maximum increase of 0.7 kPa.

DISCUSSION

The present data on the interrelation between postoperative chest X-ray abnormalities, arterial hypoxemia and clinically registered respiratory complications are based on findings in 52 out of totally 91 patients, 40–75-year-old male patients admitted to the hospital for surgery because of gallbladder disease or peptic ulcer during the study period. In 34 patients preoperative assessment was not performed either due to reluctance to participate or to earlier than planned admission to hospital allowing no time for preoperative examinations according to the study programme. In terms of age, smoking habits and length of hospital stay, no significant differences were found between those included and not included in the presentation. The percentage of clinically registered pulmonary complications did not differ between the two groups and we have no reason to believe, although our material is small, that our data would not be representative of the average 40–75-year-old man eligible for surgery because of gallbladder disease or peptic ulcer.

The patients' respiratory function after operation was not systematically examined by the responsible clinician and hence only patients with overt signs and symptoms of respiratory complications were registered. It is well known that in studies where clinical signs of postoperative pulmonary complications are based on systematic auscultation of the lungs, the incidence of pulmonary complications is much higher than in the present study (King; Wightman). Considering the impaired ability to cough after the operation with subsequent accumulation of secretion in the bronchi, it is not surprising to find a higher frequency of respiratory complications in prospective studies based on physical examination of the patients after operation than in retrospective studies based on complications registered in the patients' records.

Respiratory complications after surgery might lead to a prolonged hospitalization and rehabilitation period and are in serious cases associated with a threat against the patient's life. From a clinical perspective it should be important to identify early cases with pulmonary complications after surgery. It is reasonable to assume that chest radiography and/or determination of arterial oxygen tension would be more sensitive methods for this early detection of respiratory complications than clinical signs. Considering the great discrepancy between

the frequency of respiratory complications registered in the patients' records and chest X-ray abnormalities it seems as if many of the respiratory complications as defined by chest radiography are without clinical significance. Even if we only count large lamellar or segmental atelectases, the incidence of chest X-ray abnormalities was 31%, i.e. 3–4 times as high as the incidence defined by clinical signs. This should not be due to interpretation bias, since all X-ray examinations were interpreted by the same radiologist who was uninformed of the patient's clinical status.

Postoperative hypoxemia as defined in this study, i.e. a difference between preoperative and postoperative arterial oxygen tension of more than 1.5 kPa was a frequent finding as almost half of the patients developed a reduction of more or equal to this magnitude. Of the 23 patients developing arterial hypoxemia only 12 had an abnormal postoperative chest X-ray. This is in accordance with the study by Hamilton *et al.* The lack of correlation between chest radiography and arterial oxygen tension could be explained by atelectases too small to be visible on the chest radiograph and/or a reduced perfusion due to micro-emboli (Lahnborg, Lagergren & Hedenstierna, 1976). Only 2 out of the 23 patients with postoperative hypoxemia were identified clinically with signs of respiratory complications. Even among the 12 patients with both arterial hypoxemia and chest X-ray abnormalities only 2 were identified clinically as having postoperative respiratory complications.

According to the study by Thorén the risk of postoperative pulmonary complications as defined by chest radiography is significantly reduced in patients who receive physiotherapy before and after the operation. All patients in this study were instructed preoperatively by a physiotherapist, all received physiotherapy after the operation and all were out of bed on the first postoperative day. In spite of this treatment every other patient had an abnormal postoperative chest X-ray and/or hypoxemia. Hence, it seems that postoperative physiotherapy in patients undergoing upper abdominal surgery will not prevent the development of atelectasis and/or hypoxemia. However, only few of these patients will develop overt signs of respiratory complications and it seems reasonable to assume that even if postoperative physiotherapy will not prevent the development of atelectasis and/or hypoxemia a more serious impairment of the re-

spiratory function is prevented by modern postoperative care including physiotherapy and early mobilization.

Our results show that the incidence of postoperative complications after upper abdominal surgery is highly dependent on methods and definitions as to what constitutes a postoperative pulmonary complication. The lack of correlation between overt clinical signs of pulmonary complications and findings at the determination of postoperative arterial oxygen tension and chest radiography is obviously of great importance when comparing the incidence of pulmonary complications in different studies and after different forms of surgery. Furthermore, such a discrepancy is important to consider when assessing risk factors and clinical consequences of respiratory complications.

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PRE- AND POSTOPERATIVE LUNG FUNCTION IN SITTING AND SUPINE
POSITION RELATED TO POSTOPERATIVE CHEST X-RAY ABNORMALITIES
AND ARTERIAL HYPOXEMIA

A clinical study on 41-72 year-old men undergoing elective
upper abdominal surgery.

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Short title: Lung function in relation to postoperative
pulmonary complications.

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SUMMARY

Spirometry in both sitting and supine position was performed before and 3-5 days after elective upper abdominal surgery in 53 men, aged 41-72 years. The results were related to postoperative respiratory complications as defined by chest radiography and measurements of the arterial oxygen tension. Preoperative TLC, FRC and WOV were lower in both positions among patients who were to develop major chest X-ray abnormalities than among patients with normal chest radiographs postoperatively. All patients who developed major chest X-ray abnormalities had a negative value for FRC-CC in supine position preoperatively, indicating "airway closure" during tidal breathing. Preoperative WOV and LCI were higher in both sitting and supine positions in patients who developed postoperative hypoxemia than in patients who did not. The postoperative decrease in TLC, FRC and WOV in sitting position was greater among patients with major X-ray abnormalities and/or arterial hypoxemia postoperatively than among patients without these complications.

According to our results, conventional spirometry in supine position is not superior to conventional spirometry in sitting position as part of pre- or postoperative assessment of patients. On the other hand, preoperative "airway closure" and arterial oxygen tension, measured in supine position, both showed a correlation with postoperative chest X-ray abnormalities.

INTRODUCTION

The relations between postoperative chest X-ray changes and pulmonary function have been studied previously by Brattström (1954) who found that FRC decreased more after high laparotomies in patients with postoperative chest X-ray abnormalities than in patients without such complications. Palmer & Gardiner (1964) and Collins, Darke & Knowelden (1968) have studied VC and FEV_{1.0} before and after upper laparotomy and related the findings to postoperative chest X-ray abnormalities. Their results were not consistent.

The association between postoperative reduction in VC and in arterial oxygen tension has been studied by Palmer & Gardiner (1964) and Diamant & Palmer (1966) who both found that the correlation was not a close one.

Pulmonary function tests are usually performed with the patients in sitting position. It is known, however, that lung volumes, ventilatory capacity and intrapulmonary gas distribution change from sitting to supine position. This applies especially to the phenomenon of "airway closure" (McCarthy et al., 1972). During anaesthesia and upper abdominal surgery the patient is in supine position. This also applies to the immediate postoperative period. However, there were no studies in which postoperative pulmonary complications have been related to changes in lung function occurring both in sitting and supine position.

The aim of the present investigation was to study pre- and postoperative lung function in sitting and supine position in 40-75 year-old men undergoing elective upper abdominal surgery and relate the findings to postoperative respiratory complications as defined by chest radiography and measurements of the arterial oxygen tension.

PATIENTS AND METHODS

Fifty-three men were studied before and after elective surgery for bile stones or peptic ulcer. Their age ranges from 41 to 72 years (median 53 years). The studied material has been presented previously by Wirén, Janzon & Hellekant (1981). Two of the patients had a history of myocardial infarction and three had chest pain on effort. Ten patients had chronic bronchitis and one had

asthma. The doctors on the wards were aware of the study but did not know the character or aim of it. The chest physiotherapists were not aware of the study.

Spirometry

Spirometry was performed twice. The first study was done within three weeks before surgery and the second study 3-5 days after surgery. Measurements were made in sitting and supine position using standard technique. Many of the patients complained of pain during the postoperative spirometry.

Vital capacity (VC), forced expiratory volume in one second ($FEV_{1.0}$) and maximal voluntary ventilation (MVV) were measured with a Bernstein-type spirometer (Berglund *et al.*, 1963; Birath, Kjellmer & Sandqvist, 1963). Functional residual capacity (FRC), residual volume (RV) and total lung capacity (TLC) were measured with a multiple breath nitrogen wash-out technique (Bouhuys, Hagstam & Lundin, 1956). The multiple breath nitrogen wash-out was also used to calculate wash-out volume (WOV), i.e. the volume of oxygen inhaled in order to reduce the nitrogen concentration in exhaled air to below 2 per cent (Arborelius *et al.*, 1974) and lung clearance index (LCI), WOV/FRC (Bouhuys, Hagstam & Lundin, 1956). The single breath nitrogen wash-out technique to measure closing capacity (CC), i.e. the volume of air remaining in the lungs when the airways start to close during exhalation and slope index (SI), i.e. the change in nitrogen concentration during the alveolar plateau have been described by Oxhøj & Bake (1974). Unfortunately, preoperative measurements of CC were not successful in all the patients. Due to pain it was not possible to perform the CC measurements postoperatively.

Since reference values for spirometric data in the supine position were not available, absolute values were used in the analyses. Mean values for age, height and body weight in patients with and without postoperative major chest X-ray abnormalities and arterial hypoxemia, respectively, are listed in Table 1. The differences between patients with and without postoperative pulmonary complications were not statistically significant.

Arterial oxygen tension

Arterial oxygen tension was measured with a Clark electrode as described by Sundström (1975). Samples of arterial blood were drawn in connection with the pre- and postoperative spirometries and additional samples were taken on the second day after surgery. The lowest postoperative value was used in the evaluation of postoperative hypoxemia.

Definition of postoperative arterial hypoxemia: Reduction of the arterial oxygen tension greater than 1.5 kPa as compared with the preoperative value. (Comparisons of two measurements in the same individuals 1-2 years apart showed a reduction greater than 1.5 kPa in only 2 %.)

Chest radiography

Posteroanterior and lateral chest radiography was performed 3-5 days postoperatively. All films were read by the same radiologist who had no information about the clinical status of the patients.

Definition of major chest X-ray abnormalities: Segmental atelectases or more than 4 cm large lamellar atelectases with or without infiltrates.

Statistical analyses

Student's two-tailed t-test was used for comparison between groups and paired t-test was used for comparison within groups. The statistical analysis was performed as described by Pedersen & Hofsten (1971).

RESULTS

Incidence of postoperative respiratory complications

Postoperative arterial hypoxemia occurred in 23 out of 53 patients (43 %). Out of 52 patients who had a postoperative chest X-ray, 28 (54 %) showed X-ray changes compatible with a postoperative pulmonary complication, 16 showing major abnormalities.

Pre- and postoperative lung function related to postoperative chest radiography

All data are given in Table 2. Only patients who developed major chest X-ray abnormalities and patients with normal postoperative chest radiographs were analysed. Patients who developed major chest X-ray abnormalities differed from those with normal postoperative chest radiographs as regards preoperative TLC (sitting and supine), WOV (sitting and supine), FRC (sitting and supine) and RV (supine). All these volumes measured preoperatively were significantly smaller in patients with major postoperative chest X-ray abnormalities. The mean preoperative arterial oxygen tension was also lower in this group. The group with major chest X-ray abnormalities showed a significantly greater postoperative decrease in TLC, FRC and WOV, all sitting, than the group with normal postoperative chest radiograph. SI increased more in the group with major chest X-ray abnormalities. The difference FRC-CC preoperatively in supine position among patients who developed major chest X-ray abnormalities (-0.5 l) and patients with normal postoperative chest radiographs (-0.2 l), respectively, is shown in Fig. 1 ($P < 0.02$). All patients who developed major chest X-ray abnormalities had a negative value of FRC-CC in supine position preoperatively. The difference FRC-CC preoperatively in the sitting position among patients who developed major chest X-ray abnormalities (0.2 l) and among patients with normal postoperative chest radiographs (0.5 l), respectively, is shown in Fig. 2 ($P < 0.05$). Preoperative values of the arterial oxygen tension below and above 9.5 kPa are also shown in Figs. 1 and 2.

Pre- and postoperative lung function in patients with and without postoperative arterial hypoxemia

All data are given in Table 3. Patients with postoperative arterial hypoxemia had higher WOV and LCI, both sitting and supine, at the preoperative investigation than patients without postoperative arterial hypoxemia. At the postoperative investigation the group with postoperative arterial hypoxemia exhibited lower ventilatory capacity as measured with MVV (sitting) and $FEV_{1.0}$ (sitting and supine). TLC and FRC in the sitting position decreased more from the preoperative to the postoperative investigation in the group with postoperative arterial hypoxemia.

DISCUSSION

To our knowledge this is the first study relating pre- and postoperative lung function in both sitting and supine position to postoperative lung complications.

There is reasonable agreement between the results of the present study and those of previous ones regarding the incidence of postoperative chest X-ray abnormalities (Wiklander & Norlin, 1957; Szczepanski, Skaarup & Staehr-Johansen, 1973). The fact that the incidence of postoperative lung complications has remained unchanged for such a long period may depend on unchanged routines but may also be due to the selection of patients.

FRC, RV and TLC were measured with the nitrogen wash-out technique. This technique has the same disadvantage as the helium technique, i.e. it might underestimate the lung volumes, for example in patients with obstructive lung disease. The mean values for TLC, FRC and WOV, measured sitting and supine were all smaller at the preoperative investigation among patients who were to develop major chest X-ray abnormalities than among patients with normal postoperative chest radiographs. To our knowledge this has not been reported earlier. To some extent this could be explained by the fact that the mean height was less among patients with major chest X-ray abnormalities than among patients with normal postoperative chest radiographs. The greater decrease in TLC, FRC and WOV in the group with major X-ray abnormalities than in the group with normal postoperative chest radiographs confirmed the observations by Brattström (1954). SI increased more postoperatively in the group with major X-ray abnormalities than in the group with normal postoperative chest radiographs, indicating an association between radiological abnormalities and uneven intrapulmonary gas distribution (Oxhøj & Bake, 1974).

It is interesting to observe that the decrease in arterial oxygen tension was of the same magnitude in the group with major X-ray abnormalities as in the group with normal chest radiographs. This is in accordance with Hamilton et al. (1964) who found that there was no correlation between postoperative changes in arterial oxygen tension and X-ray abnormalities.

The group of patients who developed hypoxemia postoperatively had higher values for WOV and LCI preoperatively as compared with the group that did not develop hypoxemia indicating lower ventilatory efficiency (Arborelius et al., 1974) in the former group.

Patients with major X-ray abnormalities and postoperative arterial hypoxemia had one thing in common, i.e. a decrease in FRC (and TLC) from the preoperative to the postoperative investigation.

The difference FRC-CC was calculated. A negative value indicates "airway closure" during normal tidal breathing (Leblanc, Ruff & Milic-Emili, 1970). "Airway closure" during tidal breathing may lead to low ventilation/perfusion ratios (Alexander et al., 1973) and may predispose to postoperative hypoxemia (Holtz, Bake & Sixt, 1979) and atelectases. In Fig. 1 the difference FRC-CC in supine position is presented in relation to the appearance of postoperative X-ray changes. It appears that all patients with major X-ray abnormalities exhibited signs of "airway closure" during normal tidal breathing at the preoperative investigation in supine position. However, "airway closure" during tidal breathing was also observed in 16 out of 21 patients without any roentgenological signs of postoperative pulmonary complications. Clearly some additional factor is needed for the development of major X-ray abnormalities. When the group with major X-ray changes was compared with those 16 patients with similar evidence of "airway closure" but without any X-ray abnormalities, no difference was found regarding respiratory symptoms (chronic bronchitis), smoking habits or other lung function variables. However, preoperative arterial oxygen tension was lower in the group that later developed major chest X-ray abnormalities, though arterial carbon dioxide tension was not increased in this group. One possible explanation for this low preoperative oxygen tension could be secretions which may also predispose to atelectases in the postoperative course.

The values for FRC-CC in the sitting position were on average lower in the group with major chest X-ray abnormalities than in the group with normal chest radiographs but the results were not as clear-cut as in the supine position.

Pulmonary function tests are usually performed with the patient in the sitting position. During and after upper abdominal surgery the patient remains in the supine position. It therefore seemed appropriate to perform the spirometries

not only in the conventional sitting position but also in the supine position. Persistent pneumoperitoneum and distended bowel might cause greater impairment of lung function in the supine than in the sitting position in the immediate postoperative period. However, this could not be confirmed in our study. On the contrary, there was a statistically significant postoperative reduction in TLC and FRC in the sitting, but not in the supine position among patients with major chest X-ray abnormalities and/or arterial hypoxemia. Moreover, preoperative spirometry in the supine position was not more informative than preoperative spirometry in the sitting position.

Our conclusion is that spirometry in the supine position as part of preoperative and/or postoperative assessment of patients is not superior to spirometry in the sitting position. On the other hand, preoperative investigations of "airway closure" and arterial oxygen tension in supine position both showed a correlation with postoperative atelectases.

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Table 1

Mean values for age, height, body weight and body mass index (BMI)
in patients with and without postoperative respiratory complications

	Patients with major post- operative chest X-ray abnormali- ties	Patients with normal post- operative chest radiographs	Patients with postoperative hypoxemia	Patients without postoperative hypoxemia
Age (years)	55	53	54	53
Height (cm)	171	178	176	176
Weight (kg)	77	78	79	77
BMI	26	25	25	25

Body mass index (BMI) = Weight/height² (Keys et al. 1972)

Table 2

Spirometric findings in relation to postoperative chest X-ray findings

I. Major chest X-ray abnormalities (n = 16)				II. Normal chest radiograph (n = 24)				Comparison between group I and group II			
	Pre	Post	Post - Pre	Pre	Post	Post - Pre	Pre	Post	Post - Pre		
VC sitting (1)	4.3	2.8	- 1.5	P < 0.001	4.9	3.7	- 1.2	P < 0.001	NS	P < 0.01	NS
VC supine (1)	4.1	2.7	- 1.4	P < 0.001	4.5	4.5	- 1.0	P < 0.001	NS	P < 0.01	NS
TLC sitting (1)	6.6	5.0	- 1.5	P < 0.001	7.5	6.6	- 0.8	P < 0.001	P < 0.02	P < 0.001	P < 0.02
TLC supine (1)	5.8	4.4	- 1.3	P < 0.001	6.8	5.9	- 0.8	P < 0.001	P < 0.01	P < 0.001	NS
FRC sitting (1)	3.4	2.9	- 0.5	P < 0.005	4.1	4.1	± 0	NS	P < 0.005	P < 0.001	P < 0.02
FRC supine (1)	2.3	2.2	- 0.1	NS	3.2	3.2	± 0	NS	P < 0.001	P < 0.001	NS
RV sitting (1)	2.3	2.2	± 0	NS	2.6	3.0	+ 0.4	NS	NS	P < 0.001	NS
RV supine (1)	1.7	1.7	± 0	NS	2.3	2.4	+ 0.2	NS	P < 0.01	P < 0.001	NS
MVV sitting (1)	141.	84.	- 57.	P < 0.001	144.	98.	- 46.	P < 0.001	NS	P < 0.001	NS
FEV ₁ sitting (1)	3.3	2.3	- 1.1	P < 0.001	3.5	2.6	- 1.0	P < 0.001	NS	NS	NS
FEV ₁ supine (1)	3.1	2.0	- 1.1	P < 0.001	3.2	2.4	- 0.8	P < 0.001	NS	NS	NS
WOV sitting (1)	32.9	28.6	- 4.3	P < 0.02	39.3	41.6	+ 2.3	NS	P < 0.05	P < 0.001	P < 0.02
WOV supine (1)	25.3	23.9	- 1.5	NS	33.3	35.0	+ 1.6	NS	P < 0.01	P < 0.001	NS
LCI sitting	9.8	9.9	+ 0.1	NS	9.6	10.1	+ 0.6	NS	NS	NS	NS
LCI supine	10.6	10.9	+ 0.3	NS	10.3	11.1	+ 0.7	NS	NS	NS	NS
SI sitting	2.0	4.0	+ 2.0	P < 0.005	2.6	3.2	+ 0.6	P < 0.001	NS	NS	P < 0.02
SI supine	2.4	4.6	+ 2.2	P < 0.001	3.1	4.1	+ 1.0	P < 0.005	NS	NS	P < 0.02
aB-PO ₂ (kPa)	9.6	8.1	- 1.5	P < 0.001	10.2	8.9	- 1.3	P < 0.001	P < 0.05	P < 0.01	NS

Table 3

Spirometric findings in relation to postoperative reduction of the arterial oxygen tension

	I. > 1.5 kPa (n = 23)				II. < 1.5 kPa (n = 30)				Comparison between group I and and group II			
	Pre	Post	Post - Pre	Pre	Post	Post - Pre	Pre	Post	Pre	Post	Post - Pre	
VC sitting (1)	4.6	3.1	- 1.5	4.7	3.6	- 1.1			NS	NS	NS	
VC supine (1)	4.3	3.0	- 1.3	4.4	3.3	- 1.1			NS	NS	NS	
TLC sitting (1)	7.2	5.8	- 1.4	6.9	6.0	- 0.8			NS	NS	P < 0.02	
TLC supine (1)	6.4	5.2	- 1.2	6.3	5.3	- 1.1			NS	NS	NS	
FRC sitting (1)	3.9	3.6	- 0.4	3.6	3.6	± 0			NS	NS	P < 0.05	
FRC supine (1)	2.9	2.8	- 0.1	2.8	2.6	- 0.1			NS	NS	NS	
RV sitting (1)	2.6	2.7	+ 0.1	2.2	2.5	+ 0.3			P < 0.025	NS	NS	
RV supine (1)	2.1	2.2	+ 0.1	1.9	2.0	± 0			NS	NS	NS	
MV sitting (1)	136.	84.	- 52.	152.	103.	- 50			NS	NS	P < 0.025	
FEV ₁ sitting (1)	3.4	2.2	- 1.2	3.6	2.7	- 0.9			P < 0.001	NS	NS	
FEV ₁ supine (1)	3.1	2.0	- 1.1	3.3	2.4	- 0.9			NS	P < 0.02	NS	
WV sitting (1)	39.4	35.8	- 3.5	32.4	35.6	+ 3.2			P < 0.001	P < 0.05	NS	
WV supine (1)	32.2	31.8	- 0.4	26.6	27.5	+ 0.9			P < 0.05	NS	NS	
LCI sitting	10.0	10.1	+ 0.1	9.2	9.9	+ 0.7			NS	P < 0.05	NS	
LCI supine	10.8	11.1	+ 0.3	9.7	10.5	+ 0.8			P < 0.001	P < 0.02	NS	
SI sitting	2.5	3.8	+ 1.3	2.3	3.1	+ 0.8			NS	NS	NS	
SI supine	2.9	4.8	+ 2.0	2.8	3.8	+ 1.0			P < 0.005	NS	P < 0.05	

Fig. 1

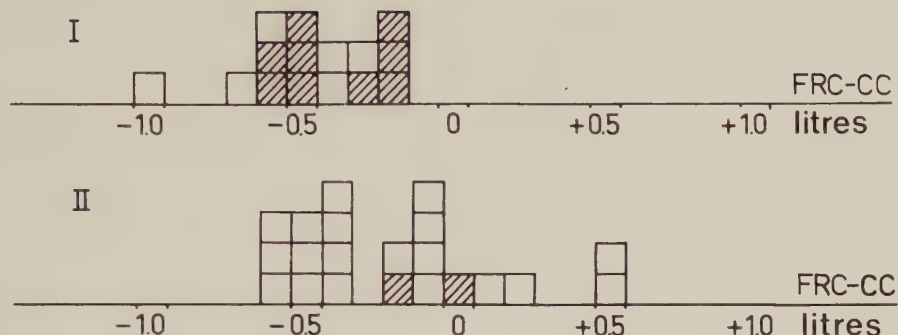


Fig. 1. Preoperative "airway closure" during tidal breathing (negative values for FRC-CC) in the supine position in patients with major chest X-ray abnormalities (I) and normal chest X-ray (II) postoperatively.

□ denotes patients with preoperative arterial oxygen tension above 9.5 kPa.
 ▨ denotes patients with preoperative arterial oxygen tension below 9.5 kPa.

Fig. 2

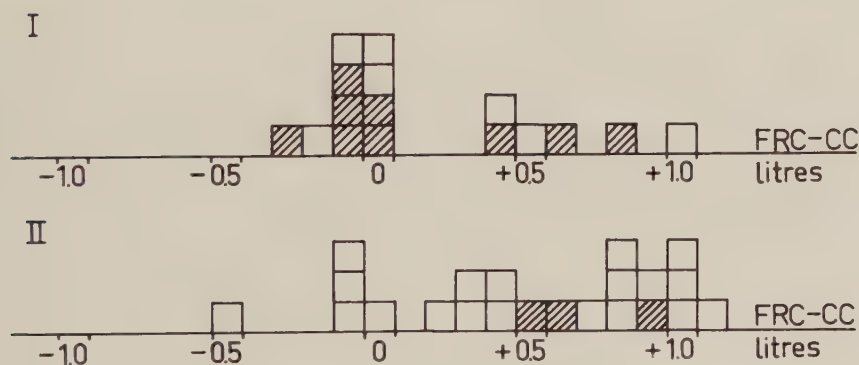


Fig. 2. Preoperative "airway" closure" during tidal breathing (negative values for FRC-CC) in the sitting position in patients with major chest X-ray abnormalities (I) and normal chest X-ray (II) postoperatively.

□ denotes patients with preoperative arterial oxygen tension above 9.5 kPa.
 ▨ denotes patients with preoperative arterial oxygen tension below 9.5 kPa.

RISK FACTORS FOR POSTOPERATIVE RESPIRATORY COMPLICATIONS AND THEIR PREDICTIVE VALUE

*A Study in 40–75-Year-Old Men Undergoing Elective Surgery
for Peptic Ulcer or Gallbladder Disease*

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Abstract. Age, body weight, smoking, chronic bronchitis and duration of anaesthesia were assessed as risk factors for respiratory complications following surgery for peptic ulcer or gallbladder disease. The studies were made on 53 men aged 40–75 years. All variables were associated with increased postoperative risk of chest X-ray abnormality or arterial hypoxaemia or clinically overt respiratory complications. In the statistical analysis, however, none of the factors proved to be useful as a predictor of postoperative respiratory complications. The observed high frequencies of X-ray abnormalities (54%) and arterial hypoxaemia (43%) after operation indicate potential dangers. They may be reduced by cessation of smoking before the operation and reduction of weight.

The risk of respiratory complications in conjunction with surgery ranges in published studies from 5 to 70%. High age, overweight, smoking, chronic bronchitis and long duration of anaesthesia are factors which in some, but not all, studies have been found to be associated with increase in this risk (Morton, 1944; Dripps & Deming, 1946; Thorén, 1954; Wiklander & Norlin, 1957; Nunn, 1965; Wightman, 1968; Latimer, Dickman, Clinton Day, Gunn & DuWayne Schmidt, 1971; Szczepanski, Skaarup & Staehr-Johansen, 1973; Hansen, Drabløs & Steinert, 1977). The lack of agreement is to some extent explained by differences in selection of patients and in surgical procedures and methods of anaesthesia.

We have previously reported that the incidence of respiratory complications after upper abdominal surgery is dependent on differences in methods and definitions (Wirén, Janzon & Hellekant, 1981). Postoperative chest X-ray abnormalities and arterial hypoxaemia were six to seven times as frequent as clinically manifest respiratory complications

registered in the patients' records. Differences in methods and definitions must therefore also be one possible explanation of conflicting opinions as to what should be regarded as risk factors for respiratory complications after surgery.

The aim of the present study was to evaluate age, body weight, smoking, chronic bronchitis and duration of anaesthesia as risk factors for postoperative respiratory complications as defined by clinical signs, chest radiography and measurements of arterial oxygen tension. The study was made on men aged 40 to 75 years who were electively operated on for gallbladder disease or peptic ulcer.

MATERIAL AND METHODS

The patients and methods have been presented in detail elsewhere (Wirén et al.). The results in the present study are based on findings in 53 men aged 40–75 years who were admitted for elective surgery to Malmö General Hospital. The operations were performed for peptic ulcer in 24 cases and for gallbladder disease in 29.

The preoperative assessment included routine physical examination, determination of arterial oxygen tension, and also an interview using a standardized questionnaire concerning smoking habits and symptoms of chronic bronchitis.

The postoperative evaluation included chest radiography and determination of arterial oxygen tension. The interval from operation to chest radiography was 3 to 5 days. The arterial oxygen tension was measured on the second day after the operation and again 3–5 days after the operation. The lowest recorded value was used for classification of postoperative arterial hypoxaemia.

When the patients had been discharged from hospital, all case records were checked for notes stating occurrence of a respiratory complication after surgery.

Definition of risk factors

1. *Smoking* was defined as regular smoking of at least 1 gram of tobacco per day for at least the past year;

Table I. Median value and range for age, body mass index and duration of anaesthesia

No. of smokers and patients with chronic bronchitis (*n*=53)

	Median	Range
Age (years)	53	41–72
Body mass index	24.6	19–32
Anaesthesia (minutes)	150	85–275
	No.	%
Smokers	32	61
Chronic bronchitis	10	19

non-smoking implied no smoking for at least a month prior to the operation.

2. *Chronic bronchitis* was defined as expectoration on most days during at least three consecutive months for more than two successive years (Medical Research Council's Committee on the Aetiology of Chronic Bronchitis, 1965).

3. *Body weight* was calculated as body mass index (BMI), i.e. weight/height² (Keys, Fidanza, Karvonen, Kimura & Taylor, 1972).

4. *Age* was that on the day of operation.

5. *Duration of anaesthesia* was measured as the time from induction to extubation. The data were collected from the patients' records.

Definition of postoperative chest X-ray abnormalities

Any atelectasis or infiltrative opacity.

Definition of postoperative arterial hypoxaemia

Reduction of the arterial oxygen tension greater than 1.5 kPa as compared with the preoperative value. (Comparisons of two measurements in the same individuals in normal circumstances showed a reduction greater than 1.5 kPa in only 2%.)

Definition of clinically registered complications

Only those cases were counted in which the attendant clinician had explicitly recorded a respiratory complication after the operation.

Statistical methods

Odds ratio (OR) was used to quantitate the degree of association between risk factors and respiratory complications. The odds ratio was calculated according to Fleiss (1973).

		Pulmonary complication		$OR = \frac{a \cdot d}{c \cdot b}$
		Yes	No	
Risk factor	Yes	<i>a</i>	<i>b</i>	
	No	<i>c</i>	<i>d</i>	

OR>1.0 indicates an association between the presumptive risk factor and respiratory complications.

When assessing body weight, age and duration of anaesthesia as risk factors, the values were divided into quartiles. For each risk factor the lowest quartile was used as reference. In the risk evaluation of smoking and chronic bronchitis, non-smoking and absence of chronic bronchitis were used as references.

The number of clinically recorded respiratory complications was too small for division into quartiles. The number of complications in patients with age, BMI and duration of anaesthesia, respectively, above the median was therefore compared with the number of complications in patients with values below the corresponding median.

The use of data from case control studies for calculation of predictive value was discussed by Galen & Gambino (1975). In the present study, the predictive value (PV) gives a measure of the probability that patients with a certain risk factor will have postoperative respiratory complications. PV is influenced by the definition of risk. The following cut-off points were used in defining risk.

Age	BMI	Duration of anaesthesia
Age $\geq Q_2$	BMI $\geq Q_2$	Duration $\geq Q_2$
Age $\geq Q_3$	BMI $\geq Q_3$	Duration $\geq Q_3$
Age = Q_4	BMI = Q_4	Duration = Q_4

Q=quartile.

RESULTS

In one of the 53 patients, postoperative chest radiography was not performed. In 28 (54%) of the other 52 patients there was abnormality of the chest radiogram. In 23 patients (43%) arterial hypoxaemia developed. Clinically recorded respiratory complications occurred in only four cases (8%).

Age, BMI, duration of anaesthesia, number of smokers and of patients with chronic bronchitis are presented in Table I. The association between these factors and postoperative chest X-ray abnormalities is shown in Table II.

Age, BMI and duration of anaesthesia in the third and fourth quartiles were all associated with increased risk of abnormal postoperative X-ray of the chest. The odds ratios ranged from 1.4 to 2.6. None of these factors proved to be useful as predictors of such abnormalities, however, since the incidence of abnormal chest X-ray in the third and fourth quartiles (54–69%) was not statistically different from the overall figure, viz. 54%.

The association between presumptive risk factors and postoperative hypoxaemia is shown in Table III. Fourth-quartile values for age, BMI and duration of anaesthesia were all associated with increased risk of hypoxaemia as compared with the first quartile. When anaesthesia exceeded three

Table II. Risk factors for postoperative chest X-ray abnormality and their predictive values

Q = quartile, OR = odds ratio

	Postoperative chest X-ray abnormality			Predictive value of	%
	No	Yes	OR		
<i>Age (years)^a</i>				<i>age:</i>	
Q ₁ (41–47)	7	6			
Q ₂ (48–52)	7	6	1.0	≥Q ₂	56
Q ₃ (53–58)	4	9	2.6	≥Q ₃	62
Q ₄ (59–72)	6	7	1.4	=Q ₁	54
<i>BMI^a</i>				<i>BMI:</i>	
Q ₁ (19.1–22.8)	7	6			
Q ₂ (22.9–24.5)	7	6	1.0	≥Q ₂	56
Q ₃ (24.6–26.8)	6	7	1.4	≥Q ₃	62
Q ₄ (26.9–31.6)	4	9	2.6	=Q ₁	69
<i>Anaesthesia duration (min)^a</i>				<i>anaesthesia duration:</i>	
Q ₁ (85–129)	7	5			
Q ₂ (130–150)	7	8	1.5	≥Q ₂	58
Q ₃ (151–179)	6	9	2.1	≥Q ₃	60
Q ₄ (180–275)	4	6	2.1	=Q ₁	60
<i>Smoking^a</i>				<i>smoking:</i>	
No	10	11			55
Yes	14	17	1.1		
<i>Chronic bronchitis^a</i>				<i>chronic bronchitis:</i>	
No	18	24			40
Yes	6	4	0.5		

^a In calculations of OR, Q₁ non-smokers and patients without chronic bronchitis, respectively, were used as reference groups.

hours, the increase in risk of hypoxaemia was five-fold as compared with anaesthesia for less than 130 min. Smoking and chronic bronchitis increased the arterial hypoxaemia risk by 1.4 and 2.3 times, respectively. None of these risk factors was found in the statistical analysis to be useful as a predictor of arterial hypoxaemia, as their predictive values (43–60%) did not differ from the overall incidence of this complication, viz. 43%.

The associations between presumptive risk factors and clinically recorded respiratory complications are listed in Table IV. Age, BMI and duration of anaesthesia appeared to be unrelated to this risk. Smoking and chronic bronchitis, on the other hand, involved a 2.1 and 1.5-fold risk, respectively, of clinically recorded complications of this type. In the statistical analysis, however, none of the predictive values (4–10%) differed from the overall figure of 8%. Consequently, none of the studied factors was useful as a predictor of clinically manifested respiratory complications of surgery.

DISCUSSION

Respiratory complications in conjunction with surgery may have serious clinical consequences. The potential for prevention is dependent on ability to detect and eliminate factors and conditions which are associated with increased risk of post-operatively impaired pulmonary function.

As a measure of association, the odds ratio has two major advantages—it is independent of sample size and provides a quantitative expression of the degree of association. In the present study, high age, overweight, smoking, chronic bronchitis and long duration of anaesthesia were shown to be risk factors with at least one of the comparative methods, although the degree of association varied. Thus, though high age and overweight were not associated with increased risk of clinically recorded respiratory complications, chest X-ray abnormalities and/or arterial hypoxaemia were more common among the old and heavy patients. These complications were also more common in smokers than in

Table III. Risk factors for postoperative arterial hypoxaemia and their predictive values

Q=quartile, OR=odds ratio

	Postoperative arterial hypoxaemia			Predictive value of	%
	No	Yes	OR		
<i>Age (years)^a</i>				<i>age:</i>	
Q ₁ (41-47)	6	7			
Q ₂ (48-52)	10	3	0.3	≥Q ₂	40
Q ₃ (53-58)	8	5	0.5	≥Q ₃	48
Q ₄ (59-72)	6	8	1.1	=Q ₄	57
<i>BMI^a</i>				<i>BMI:</i>	
Q ₁ (19.1-22.8)	8	5			
Q ₂ (22.9-24.5)	8	5	1.0	≥Q ₂	45
Q ₃ (24.6-26.8)	6	7	1.9	≥Q ₃	48
Q ₄ (26.9-31.6)	8	6	1.2	=Q ₄	43
<i>Anaesthesia duration (min)^a</i>				<i>anaesthesia duration:</i>	
Q ₁ (85-129)	10	3			
Q ₂ (130-150)	8	7	2.9	≥Q ₂	50
Q ₃ (151-179)	8	7	2.9	≥Q ₃	52
Q ₄ (180-275)	4	6	5.0	≥Q ₄	60
<i>Smoking^a</i>				<i>smoking:</i>	
No	13	8			47
Yes	17	15	1.4		
<i>Chronic bronchitis</i>				<i>chronic bronchitis:</i>	
No	26	17			60
Yes	4	6	2.3		

^a In calculations of OR, Q₁ non-smokers and patients without chronic bronchitis, respectively, were used as reference groups.

non-smokers and after protracted than after shorter duration of anaesthesia. The association of anaesthesia duration with arterial hypoxaemia and chest X-ray abnormality was accentuated by stepwise increased risk with prolongation of anaesthesia.

For correct assessment of the predictive value of various risk factors, prospective studies of large numbers of patients are necessary. Such studies, however, are costly and time-consuming. Galen & Gambino therefore suggested use of data from case control studies in order to obtain a spot estimate of 'true' predictive value.

In the ideal situation it would of course be possible to identify preoperatively all patients who will, and those who will not have respiratory complications after surgery. The predictive value of a given risk factor depends on the definition of that risk. For instance, if BMI in the upper quartile is defined as a risk factor for postoperative X-ray abnormality of the chest, the accuracy of prediction in the present study would be 69%. This also implies that

31% of the patients with BMI in the upper quartile would have been erroneously identified as being at risk. With the same definition of risk, patients with BMI below the fourth quartile would be classified as not subject to risk. Nevertheless, in 49% of these patients there was chest X-ray abnormality after operation, and therefore the no-risk classification would have been incorrect. Use of an even higher cut-off point in the definition of risk, though increasing the predictive value, would also increase the number of false-negative predictions.

In order to establish criteria of risk, one must consider the consequences of incorrect identification as high-risk patients. Observation for early signs of respiratory complications would probably be intensified in these patients, as would physiotherapy. Chest radiography and measurement of arterial oxygen tension would possibly be done more frequently both before and after surgery. Potentially this would increase the workload for ward and laboratory personnel, though none of the

Table IV. Risk factors for clinically registered respiratory complications of surgery and their predictive values

OR=odds ratio, PV=predictive value. In calculations of OR, patients with values below the median of age, BMI and anaesthesia time, and non-smokers and patients without chronic bronchitis, respectively, were used as reference groups

	Clinically registered respiratory complications		OR	PV (%)
	No	Yes		
<i>Age (years)</i>				
Below 53	23	3		
Above 53	26	1	0.3	4
<i>BMI</i>				
Below 24.6	23	3		
Above 24.6	26	1	0.3	4
<i>Anaesthesia duration (min)</i>				
Below 150	22	2		
Above 150	27	2	0.8	7
<i>Smoking</i>				
No	20	1		
Yes	29	3	2.1	9
<i>Chronic bronchitis</i>				
No	40	3		
Yes	9	1	1.5	10

measures would be associated with danger to the patient.

A false negative classification, on the other hand, i.e. classifying a high-risk patient as no-risk, could increase the danger that early signs of respiratory complications will be disregarded. This could prolong the hospital stay and delay rehabilitation, and in serious cases even be life-threatening. For these reasons, the aim in definition of risks should be to identify the majority of high-risk individuals prior to surgery, even if this involves inclusion of some patients who, in fact, are not at risk.

Our study included only patients undergoing elective surgery and therefore it is not representative for all individuals with gallbladder disease and/or peptic ulcer. On the other hand, there seems to be no reason to doubt that the series is representative for the average male patient in corresponding age groups who is admitted for surgery on an elective basis.

Although the studied factors were demonstrated

to signify risk in at least one of the analyses, the associations were not strong enough to identify high-risk individuals prior to surgery. Selection of patients may have been a contributory reason, since persons with severely impaired lung function or grossly overweight or old patients and heavy smokers with chronic bronchitis might not have been offered elective surgery. Such selection narrows the spectrum of risk. In addition, all the patients received instruction from a physiotherapist before the operation and were mobilized as quickly as possible afterwards.

The high incidence of chest X-ray abnormality and arterial hypoxaemia in patients undergoing surgery for peptic ulcer or gallbladder disease should be kept in mind. These complications may have serious clinical consequences. Whether or not preoperative cessation of smoking and weight reduction and shortening the operation time can reduce the risk of such complications must be tested in prospective, controlled studies.

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RESPIRATORY COMPLICATIONS FOLLOWING SURGERY
Improved prediction with preoperative spirometry

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Short title: Respiratory complications following surgery.

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ABSTRACT

Patients who are old, overweight, who smoke and/or have symptoms of respiratory disease have an increased risk of atelectases and/or arterial hypoxemia in conjunction with surgery. The present study in 53 middle-aged men operated on for gallbladder or peptic ulcer disease, illustrates how spirometry can be used to improve the prediction of respiratory complications. The relative risk of atelectases was greater in patients with FRC-CC below - 0.1 l and the risk prediction based on age, body weight, smoking habits and respiratory symptoms was improved by adding information on FRC-CC. Arterial hypoxemia was more common in patients with WOV above than below 35 l. The preoperative identification of high risk patients of arterial hypoxemia based on above-mentioned risk factors, was improved by adding information on WOV.

KEY WORDS

Abdominal surgery; airway closure; arterial hypoxemia; atelectasis; risk factors.

Several studies have shown that old people, people who are obese, who smoke and who have chronic bronchitis as groups have an increased risk of respiratory complications following surgery (1,2,3,4). However, so far prediction of postoperative complications in the individual patient on the basis of these risk factors has not been feasible (5,6,7).

A number of studies have analysed the importance of the preoperative respiratory function for postoperative respiratory complications. In general, preoperative spirometry has revealed a reduced ventilatory capacity in cases with complications (4,5). The spirometric variable most strongly associated with these complications varies between studies, however (6,8,9,10). This is partly explained by differences in the method of study. We have previously found that "airway closure" within tidal volume (negative FRC-CC) is associated with postoperative chest X-ray abnormalities, whereas an increased wash-out volume (WOV) is associated with postoperative arterial hypoxemia (11).

The aim of the present study was to assess if preoperative determination of FRC-CC and WOVI will improve the risk assessment based on age, body weight, smoking habits and respiratory symptoms.

MATERIAL AND METHODS

The study is based on findings in 53 men, 41-72 years old, who were admitted to the Department of Surgery, Malmö General Hospital, because of gallbladder or peptic ulcer disease. All underwent operation on an elective basis. In terms of surgical and anaesthesiological procedure the material has been described in detail earlier (12).

The preoperative assessment included measurements of height and weight, questions on smoking habits and respiratory symptoms, spirometry and measurement of the arterial oxygen tension.

Smoking was defined as regular smoking of at least one gram of tobacco per day for at least the past year. Thirty-two of the patients were smokers (61 %).

Non-smoking implied no smoking for at least one month prior to the operation.

Chronic bronchitis was defined as expectoration on most days during at least three consecutive months for more than two successive years (13). Ten patients fulfilled the questionnaire criteria for chronic bronchitis. All of them were smokers.

Body weight was calculated as body mass index (BMI), i.e. weight (kg)/height (m)² (14). BMI varied from 19-32 with a median of 24.6.

Median age was 53 years, ranging from 41 to 72.

Functional residual capacity (FRC) was measured with a multiple breath nitrogen wash-out technique (15). This technique was also used to calculate wash-out volume (WOV), i.e. the volume of oxygen inhaled in order to reduce the nitrogen concentration in exhaled air to below 2 % (16). The single breath nitrogen wash-out technique (17) was used to measure closing capacity (CC), i.e. the volume of air remaining in the lungs when the airways start to close during exhalation. The preoperative measurements of CC were successful in 49 of the patients. The difference FRC-CC was calculated. A negative value indicates "airway closure" during normal tidal breathing (18). In the present study, FRC-CC was measured in supine position and wash-out volume was measured in sitting position because of the associations to postoperative respiratory complications found in an earlier study (11).

The postoperative evaluation included chest radiography and determination of the arterial oxygen tension. The interval from operation to chest radiography was 3 to 5 days. The arterial oxygen tension was measured on the second day after the operation and again 3-5 days after the operation. The lowest recorded value was used for classification of postoperative arterial hypoxemia.

Definition of postoperative chest X-ray abnormalities:

Any atelectasis or infiltrative opacity.

Definition of postoperative arterial hypoxemia:

Reduction of the arterial oxygen tension greater than 1.5 kPa from the pre-operative value.

Statistical methods:

The odds ratio, OR, was used to quantitate the degree of association between risk factors and respiratory complications. The odds ratio was calculated according to Fleiss (19).

		<u>Pulmonary complications</u>		
		Yes	No	
Positive test	Yes	a	b	Sensitivity = $\frac{a}{a + c}$
	No	c	d	
OR = $\frac{a \cdot d}{c \cdot b}$				Specificity = $\frac{d}{b + d}$

OR > 1.0 indicates an association between the presumptive risk factor and respiratory complications.

The predictive value was calculated according to Galen & Gambino (20).

$$\text{Predictive value of positive test (PV+)} = \frac{a}{a + b}$$

$$\text{Predictive value of negative test (PV-)} = \frac{d}{c + d}$$

The predictive value of a positive test gives a measure of the probability that patients with a certain risk factor will have a respiratory complication postoperatively. The predictive value of a negative test gives a measure of the probability that patients without this risk factor will be free from complications.

Odds ratio and predictive values were calculated for two different risk strata. Risk and predictive values were first calculated for all smokers, all with an age above the median, all with a body weight above the median and all with chronic bronchitis. The next risk assessment involved only those of the above-mentioned patients who had an FRC-CC below - 0.1 l and a WOV above 35 l, respectively.

The risk for those two strata was compared with that for patients who were without these risks and whose FRC-CC and WOV were above and below the defined cut-off points.

RESULTS

Postoperative chest radiography was not carried out in one patient. Among the remaining 52 patients, 28 (54 %) developed chest X-ray abnormalities. Table 1 summarizes the risks and predictive values associated with the different risk strata. Patients with FRC-CC below - 0.1 l had a greater risk of postoperative atelectases than patients with an FRC-CC above this value. The preoperative identification of patients who would and would not develop respiratory complications based on their smoking habits, age, BMI and respiratory symptoms was in all cases improved by adding information on FRC-CC. The predictive value using the combined risk assessment varied between 67 and 75 %:

Twenty-three patients (43 %) developed arterial hypoxemia. Table 2 summarizes the predictive values of defined risk factors in the development of hypoxemia. The association to the mentioned risk factors was improved by adding the spirometric information. The relative risk for those with a WOV above 35 l and who smoked, had chronic bronchitis, had an age above the median or a BMI above the median varied between 3.8 and 9.0 as compared to 2.0-4.2 for all of the patients with risk factors. The predictive value having the combined information ranged from 54 to 67 % as compared to 47 to 60 % with only information on age, body weight, smoking habits and respiratory symptoms.

DISCUSSION

The incidence of postoperative chest X-ray abnormalities and arterial hypoxemia in patients undergoing upper abdominal surgery is high. Although few of these patients develop clinically overt respiratory complications, atelectases and arterial hypoxemia can be considered as potentially serious complications. The association to age, body weight, smoking and respiratory symptoms illustrates that a respiratory complication following surgery is not a random phenomenon. Some of these complications are potentially preventable by preoperative intervention on overweight, smoking habits and respiratory symptoms.

Although our study is based on a small number of patients, it is obvious that a prediction based on age, body weight, smoking habits and respiratory symptoms can be improved by preoperative assessment of FRC-CC and WOV. A preoperative risk assessment would ideally lead to identification of all who will or will not develop a respiratory complication. The sensitivity and specificity of FRC-CC and WOV, respectively, depend on the cut-off values used in the definition of a spirometric risk. Since sensitivity and specificity are inversely related, obviously one cannot have both a high sensitivity and a high specificity. Therefore, the definition of high and low risks in terms of FRC-CC and WOV has to be decided upon by considering the consequences of an incorrect classification of high and low risk patients. The consequences associated with an incorrect identification of low risk patients are, as we have earlier pointed out (7), greater than the risk of an incorrect identification of patients at high risk. Hence, one should use wide criteria in the definition of an abnormal FRC-CC and WOV, respectively. The cut-off points used in our study, $\text{FRC-CC} < -0.1 \text{ l}$ and $\text{WOV} > 35 \text{ l}$, respectively, led to correct identification of up to 75 % of high risk patients, based on their age, body weight, smoking habits and respiratory symptoms. The material was too small to assess whether a higher cut-off point for FRC-CC would further improve the preoperative identification of high risk patients.

Our study illustrates how spirometry can improve a preoperative risk assessment based on physical examination and questionnaire. In this study we used two different methods to assess the incidence of respiratory complications. Post-operative atelectases and arterial hypoxemia were associated with different spirometric variables. Whether this means that atelectases and hypoxemia reflect two different types of complications with different causes, remains to be seen in future studies.

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TABLE 1

Predictive values of defined risk factors in the development of postoperative chest X-ray abnormalities.

	Postoperative chest X-ray abnormalities			Predictive value	
	Yes	No	OR	Positive test %	Negative test %
<u>Smoking</u>					
NS with FRC-CC > - 0.1 l	1	4			
S	16	12	5.3	57	
S with FRC-CC < - 0.1 l	14	7	8.0	67	71
<u>Chronic bronchitis</u>					
NCB with FRC-CC > - 0.1 l	3	5			
CB	3	7	0.7	30	
CB with FRC-CC < - 0.1 l	3	1	5.0	75	100
<u>Age</u>					
Age bm + FRC-CC > - 0.1 l	1	5			
Age am	15	9	8.3	63	
Age am + FRC-CC < - 0.1 l	13	5	13.0	72	67
<u>BMI</u>					
BMI bm + FRC-CC > - 0.1 l	3	7			
BMI am	16	8	4.7	67	
BMI am + FRC-CC < - 0.1 l	16	6	6.2	73	100
OR = odds ratio NCB = patients without chronic bronchitis PV = predictive value CB = patients with chronic bronchitis NS = non-smokers bm = below the median S = smokers am = above the median					

In the calculations of OR the first listed group for each risk factor was used as a reference group.

TABLE 2

Predictive values of defined risk factors in the development of postoperative arterial hypoxemia.

	Postoperative arterial hypoxemia			Predictive value	
	Yes	No	OR	Positive test %	Negative test %
<u>Smoking</u>					
NS with WOV ≤ 35 l	4	9			
S	15	17	2.0	47	
S with WOV > 35 l	10	6	3.8	63	69
<u>Chronic bronchitis</u>					
NCB with WOV ≤ 35 l	7	18			
CB	6	4	3.9	60	
CB with WOV > 35 l	4	2	5.1	67	50
<u>Age</u>					
Age bm + WOV ≤ 35 l	3	12			
Age am	13	14	3.7	48	
Age am + WOV > 35 l	7	6	4.7	54	57
<u>BMI</u>					
BMI bm + WOV ≤ 35 l	2	9			
BMI am	13	14	4.2	48	
BMI am + WOV > 35 l	6	3	9.0	67	61

OR = odds ratio

NCB = patients without chronic bronchitis

PV = predictive value

CB = patients with chronic bronchitis

NS = non-smokers

bm = below the median

S = smokers

am = above the median

In the calculations of OR the first listed group for each risk factor was used as a reference group.

THE CLINICAL SIGNIFICANCE OF POSTOPERATIVE CHEST X-RAY ABNORMALITIES, ARTERIAL HYPOXEMIA AND CLINICALLY RECORDED RESPIRATORY COMPLICATIONS

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Abstract. The clinical consequences of postoperative complications as defined by signs and symptoms, chest radiography and measurements of the arterial oxygen tension were studied in 53 men, aged 40-75, who were electively operated for peptic ulcer or gallbladder disease. Clinical signs of a respiratory complication were detected in 4 patients. Of the 28 patients with chest X-ray abnormalities and 23 with arterial hypoxemia only 2 had clinical signs of a disordered pulmonary function. None of the remaining patients with arterial hypoxemia and/or chest X-ray abnormalities required any specific treatment. Hospital stay was not prolonged in patients with respiratory complications. Arterial hypoxemia and chest X-ray abnormalities in patients without clinical signs of a disordered pulmonary function had no influence on postoperative course or rehabilitation and were in all cases reversible without treatment.

Although the incidence of postoperative respiratory complications has been frequently studied, little has been published on how these complications influence the postoperative course and rehabilitation. Postoperative chest X-ray abnormalities seem, however, to have little clinical significance. In one study by Rudnikoff & Headland (1951) only one out of three patients with chest X-ray abnormalities required specific treatment. In another study by Wiklander & Norlin (1957) hospital stay was not prolonged in patients with postoperative atelectases.

The incidence of respiratory complications depends to a great extent on methods of study. We have earlier reported that in male patients undergoing elective upper abdominal surgery 54% developed chest X-ray abnormalities and 43% arterial hypoxemia, whereas clinical signs of respiratory complications were recorded in only 8%. Hence for proper assessment of the clinical significance of respiratory complications one has to consider

the criteria that have been used in the definition of these complications.

The aim of the present study was to assess if and how the postoperative course in hospital and the rehabilitation after dismissal are affected by respiratory complications as defined by clinical signs, chest radiography and measurement of the arterial oxygen tension.

MATERIAL AND METHODS

Material and methods have been presented in detail earlier (Wirén, Janzon & Hellekant, 1981). The study was restricted to 40-75 year old men, electively admitted for surgery because of peptic ulcer or gallbladder disease. In all 53 men were examined. The preoperative assessment included measurements of the arterial oxygen tension, spirometry, exercise test, physical examination and questions on smoking habits and chronic bronchitis.

The postoperative evaluation 2-5 days after surgery included measurements of the arterial oxygen tension and chest radiography. The postoperative course in hospital was assessed by retrospective review of notes, temperature curves and other pertinent data in the hospital records. All patients were given preoperative breathing instructions and postoperative physiotherapy by a physiotherapist. The patients were re-examined at a follow-up 1-2 years after surgery. The follow-up included an interview for retrospective assessment of the time period following dismissal from hospital. The questionnaire used at the follow-up contained questions on cough, phlegm, pain when breathing and shortness of breath the first 2-3 weeks after dismissal from hospital. The follow-up examination included a graded exercise test, spirometry in the sitting position, measurements of the arterial oxygen tension and chest radiography.

Four patients could not be reached for the interview. Four of the patients who were interviewed did not come to the follow-up examination. The postoperative course in these patients was not significantly different from that in the patients included in the follow-up.

Hospital stay represents the time from surgery to the

Table 1. Body temperature 3 days after surgery, length of hospital stay and presence of symptoms from the respiratory tract in patients with and without postoperative respiratory complications

	Body temperature 3 days after surgery (°C) (median + range)	Length of hospital stay (days) (median + range) Operation because of:		Symptoms from the respiratory tract after dismissal
		Peptic ulcer	Gallbladder disease	
Chest X-ray abnormalities				
Yes, major	37.4 (36.5–39.5)	6 (5–8)	5 (3–7)	2/15
Yes, minor	37.4 (36.6–38.1)	6 (5–6)	4 (4–7)	2/12
No	37.2 (36.7–38.8)	6 (4–8)	4 (3–18)	6/21
Arterial hypoxemia				
Yes	37.4 (36.7–39.5)	6 (4–8)	5 (3–11)	7/22
No	37.3 (36.6–38.8)	6 (4–8)	4 (3–18)	3/27
Clinical signs of respiratory complications				
Yes	37.2 (36.8–39.5)	6	7 (5–18)	3/4
No	37.3 (36.6–38.8)	6 (4–8)	4 (3–11)	7/45

day of dismissal. Body temperature represents the body temperature in the morning of the third day after surgery.

Pulmonary complications were defined as:

Chest X-ray abnormalities. Major: Segmental atelectases or more than 4 cm large lamellar atelectases with or without infiltrates. Minor: Less than 4 cm lamellar atelectases and/or small infiltrates.

Arterial hypoxemia. Postoperative arterial hypoxemia was defined as a reduction of more than 1.5 kPa in comparison with the preoperative value.

Clinical signs of respiratory complications. Only cases where it was explicitly stated in the charts by the clinician on the ward that the patient had suffered from a respiratory complication were encountered.

Statistical analyses

Student's two-tailed *t*-test was used for comparison between groups (Pedersen & Hofsten, 1971).

RESULTS

In only 4 cases, 8%, were there notes in the charts indicating clinical signs and/or symptoms of a respiratory complication. One of these was a 43-year-old smoker with postoperative dyspnea. The chest radiography revealed a major atelectasis. He was treated with antibiotics. The second patient, a 71-year-old smoker, had a history of chronic bronchitis. Postoperatively he developed signs indicating exacerbation of his bronchitis. He was treated with physiotherapy. The third patient, a 44-year-old ex-smoker, had signs of an upper respiratory tract infection, that did not require treatment with antibiotics. The fourth patient, a 43-year-old smoker,

got a pulmonary embolus and was treated with heparin and dicumarol. One of the 53 patients had not been submitted for postoperative chest radiography. Of the remaining 52 patients, 28 (54%) had an abnormal chest radiograph. Sixteen of these 28 patients (57%) had major abnormalities. Two of the patients with major chest X-ray abnormalities had clinical signs of a respiratory complication. One of these was the patient with an atelectasis treated with antibiotics. The other was the patient with exacerbation of his chronic bronchitis. Of the remaining 26 patients with chest X-ray abnormalities none was given any specific treatment.

Arterial hypoxemia was detected in 23 patients (43%). Only 2 of these patients had clinical signs of respiratory complications. One was the patient with an atelectasis treated with antibiotics. The other one was the patient with exacerbation of his chronic bronchitis. Of the remaining 21 patients with postoperative hypoxemia none required specific treatment.

Body temperature

Body temperature three days after surgery in relation to respiratory complications is illustrated in Table 1. The mean temperature in 11 patients who did not develop any form of respiratory complications after surgery was $\star$. The mean body temperature in patients with respiratory complications, either clinically diagnosed, chest X-

$\star 37.5 \pm 0.5^\circ\text{C}.$

ray abnormalities and/or arterial hypoxemia was not significantly different from the mean body temperature in this control group.

Length of hospital stay

The mean length of hospital stay after operation because of peptic ulcer was 6 days. Hospital stay in patients with chest X-ray abnormalities and/or arterial hypoxemia was not longer than in patients without these complications. The median length of hospital stay in patients operated on because of gallbladder disease was 4 days. No difference was found when comparing length of hospital stay in patients with and without respiratory complications.

Symptoms from the respiratory tract 2-3 weeks after dismissal

Ten patients claimed symptoms from the respiratory tract after dismissal from hospital. Seven of these were smokers and 3 were ex-smokers. The number of patients with cough, phlegm, pains when breathing and dyspnea was not greater in patients with chest X-ray abnormalities than in patients without. However, in patients with postoperative hypoxemia and/or clinical signs of respiratory complications symptoms from the respiratory tract after dismissal were 3-5 times more common than in patients without postoperative hypoxemia and clinical signs of respiratory complications, respectively.

Exercise test, spirometry and arterial oxygen tension in the follow-up examination

No difference was found between presurgery and follow-up results from the exercise test, spirometry and arterial oxygen tension neither among patients with prior respiratory complications nor among patients without such complications.

Chest radiography

The postoperative chest X-ray abnormalities had disappeared in all cases at the follow-up study.

DISCUSSION

The study group represents consecutive patients recruited during a one year time period. Hence it seems reasonable to consider the patients in this study representative for the average male patient in corresponding age groups admitted to the hos-

pital on an elective basis for surgery because of peptic ulcer or gallbladder disease. Since the present study was confined to patients who had been admitted for surgery on an elective basis the study material can of course not be considered representative for all men operated because of peptic ulcer or gallbladder disease. It might be that certain high risk patients, i.e. patients with serious overweight, asthma or chronic bronchitis have not been admitted for surgery on an elective basis.

Although major chest X-ray abnormalities and/or arterial hypoxemia was found in 60% of the patients these complications seem to have little clinical significance. Body temperature the third day after surgery was in this study used as a parameter of the clinical course after surgery. Patients with chest X-ray abnormalities and/or arterial hypoxemia did not have higher body temperature than patients without these complications. Only 2 out of 39 patients with chest X-ray abnormalities and/or arterial hypoxemia had been given specific treatment. Hospital stay was not prolonged in patients with respiratory complications as defined by chest X-ray and/or measurements of the arterial oxygen tension.

Data on respiratory symptoms during the first 2-3 weeks after surgery were obtained at an interview about one year after surgery and should therefore be used with caution. The interviewer was, however, unaware of the patients' physical status after surgery. None of the patients who had respiratory tract symptoms after dismissal required any specific treatment. Although respiratory tract symptoms were more common in patients with arterial hypoxemia and/or clinical signs of respiratory complications it did not seem at the follow-up interview as if the rehabilitation had been delayed by these complications.

Smoking has been identified as an important risk factor for postoperative hypoxemia and chest X-ray abnormalities. All patients with clinical signs of respiratory complications and all patients who claimed respiratory symptoms after dismissal had been smokers for many years.

At the follow-up examination all patients had a normal oxygen tension and a normal chest radiograph and obviously the postoperative hypoxemia and chest X-ray abnormalities were reversible without treatment. The time of their disappearance cannot be assessed from the present study.

Since neither chest X-ray abnormalities nor

arterial hypoxemia seem to have any consequences for the postoperative course or the rehabilitation outside the hospital one can question their validity as markers of respiratory complications. We have earlier reported, however, that chest X-ray abnormalities as well as arterial hypoxemia are associated with an impaired lung function as assessed with spirometry 3–5 days after surgery. The fact that few patients develop clinical signs and symptoms of respiratory complications and that few of these patients require specific treatment does not necessarily mean that these abnormalities are without clinical significance. Instead we think it is important to consider chest X-ray abnormalities as well as arterial hypoxemia as early signs of potentially serious respiratory complications. Since all patients were given preoperative breathing instructions and postoperative physiotherapy and since all were mobilized early it seems reasonable to conclude that modern care can prevent a more

serious development of these complications. Since in all cases the postoperative chest X-ray abnormalities were reversible without specific treatment it does not seem necessary to submit all patients with postoperative chest X-ray abnormalities for a routine radiographic check-up after dismissal.

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